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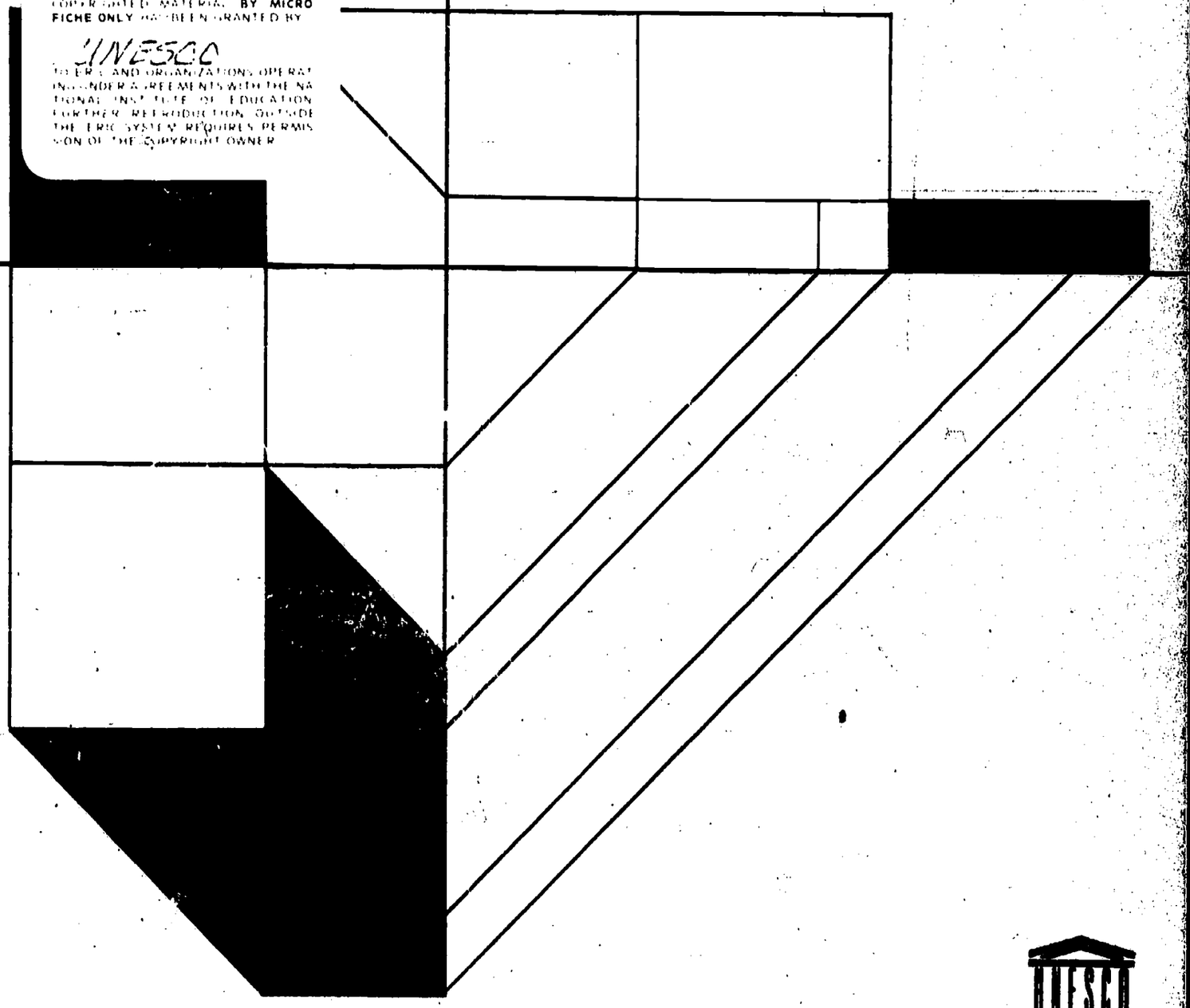
ABSTRACT

This publication provides data on the angles governing the design of sunshading devices for educational buildings in the countries of the Asian region and gives examples of the ways in which these data can be used. Different methods of excluding direct sunlight from teaching spaces are illustrated in a series of diagrams that show exclusion by roof overhang, louvres, adjustable shutters, and grills. Sunshading diagrams for latitudes 32 degrees North to 10 degrees South give the angle of the sun for a variety of building orientations. These angles can be used without further calculation to determine the projection of a sunshade that will exclude sun from the opening it protects. (Author/MLF)

SUN SHADING DIAGRAMS FOR SCHOOL BUILDINGS



EDUCATIONAL BUILDING REPORT 2

UNESCO REGIONAL OFFICE FOR EDUCATION IN ASIA
P.O. BOX 1425, BANGKOK

THE DESIGN *on the cover derives from a cube, lit from a point source. The sides in shade and in light, as well as the cast shadows, are determined by projection, the lines of which form part of the design.*

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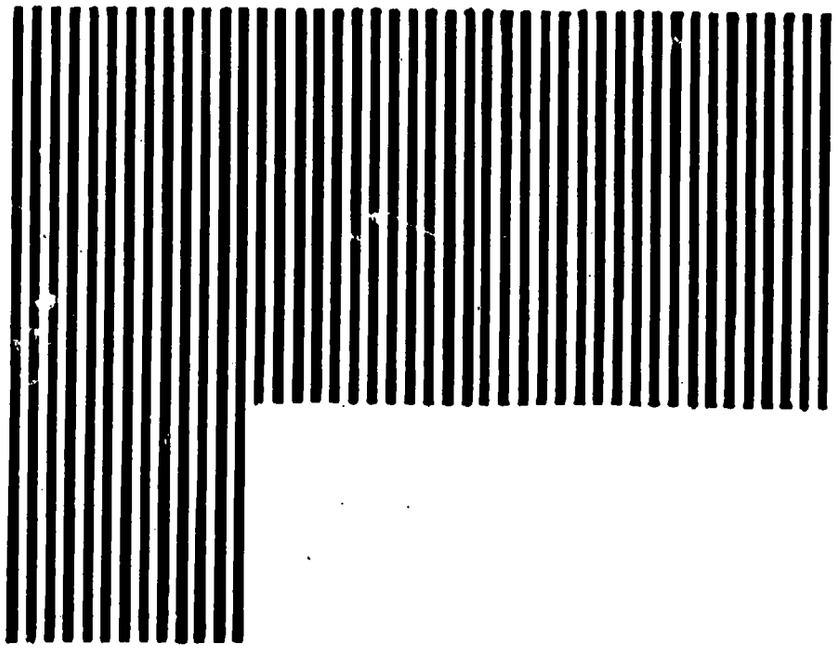

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BANGKOK

CONTENTS

SUMMARY

This publication provides data on the angles governing the design of sunshading devices for educational buildings in the countries of the Asian region and gives examples of the ways in which these data can be used. Different methods of excluding direct sunlight from teaching spaces are illustrated in a series of diagrams which show exclusion by roof overhang, louvres, adjustable shutters and grills. Planting of suitable shade trees is also recommended as a way of reducing solar heat.

Of course, a good way of keeping the cost of sunshades as well as solar heat load to a minimum is to orientate the building with its longitudinal axis east-west. This orientation may, however, sometimes conflict with the need in the humid tropics to face the building towards the prevailing breezes so that the occupants receive adequate ventilation for cooling. In such cases a compromise orientation must be sought. In the hotter and drier areas of the Asian region, smaller windows, normally provided to reduce heat gain, also make sunshading problems easier to solve.

The sunshading diagrams for latitudes 32° N to 10° S, to be found at the end of the publication, give the angle of the sun with the ground at right angles to the face of the building for a variety of building orientations. These angles can, as is shown in the examples, be used directly and without further calculation, to determine the projection of a sunshade which will exclude sun from the opening it protects.

SOMMAIRE

Cette publication fournit des données chiffrées concernant les angles et inclinaisons à donner aux dispositifs parc-soleil des écoles d'Asie, ainsi que divers exemples de la façon d'utiliser ces données. Une série de diagrammes montrent diverses méthodes de protéger les classes du rayonnement solaire direct: toits débordants jalousies, persiennes réglables et claustras. On recommande aussi de planter des arbres appropriés afin de rafraîchir l'atmosphère.

Assurément, un excellent moyen de minimiser tant le coût de ces dispositifs que l'échauffement dû au rayonnement solaire consiste à orienter les bâtiments selon un axe est-ouest. Cependant, cette orientation peut parfois être incompatible avec la nécessité, dans les régions tropicales humides, de construire les façades perpendiculairement à la direction des vents dominants afin d'assurer aux occupants une fraicheur suffisante par ventilation naturelle. En pareil cas, il faut rechercher le meilleur compromis. Dans les pays plus

chauds et plus secs d'Asie, la protection contre le rayonnement solaire est facilitée grâce aux faibles dimensions des fenêtres, traditionnellement réduites pour limiter l'échauffement des locaux.

Les diagrammes valables pour les latitudes comprises entre 32° N et 10° S, qu'on trouvera à la fin de l'ouvrage, indiquent la hauteur du soleil au-dessus de l'horizon, mesurée perpendiculairement à la façade pour diverses orientations de l'édifice. Comme le montrent les exemples donnés, on peut utiliser ces valeurs angulaires directement et sans autre calcul pour déterminer la projection d'un parc-soleil protégeant complètement l'ouverture sur laquelle il est placé.

INTRODUCTION

In most countries of the Asian region,[1] exclusion of direct sunshine from the school building is an important step toward a thermally and visually comfortable environment for pupils and teachers, as direct sunshine admitted to the building through windows and other openings will produce heat and glare (Plate 1).

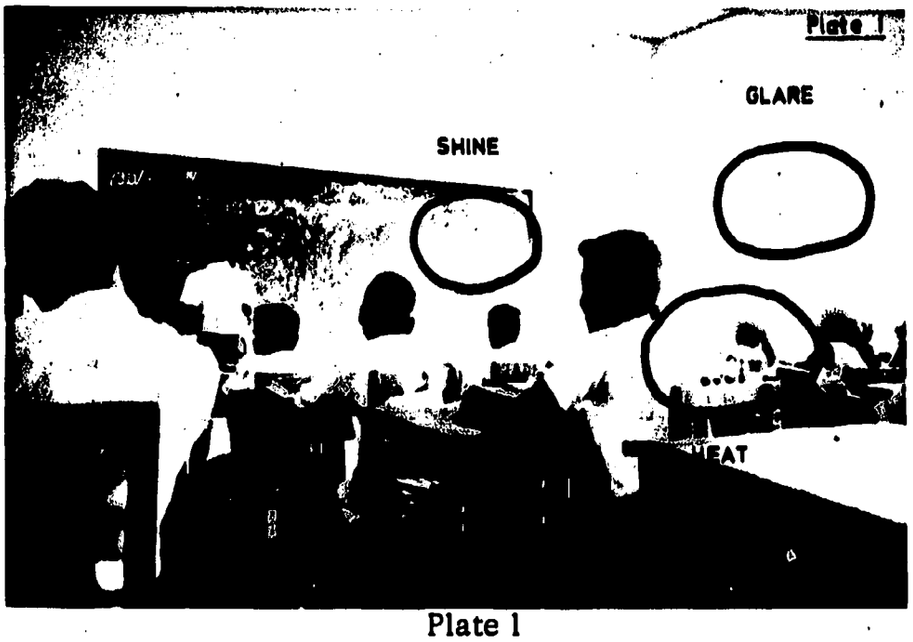

Plate 1

It is surprising how few buildings in the tropics are effectively shaded against the sun, despite the availability of excellent shadow angle protractors for the determination of horizontal and vertical sun/angles at any time of the day and for any day of the year.[2] The use of these protractors is recommended in the more complex cases. This publication provides information for most of the common cases and offers a method by which the designer's task is made simpler and less time consuming.

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1. In the mountainous areas of some countries such as in the Republic of Afghanistan, India, Iran, Republic of Korea, Nepal and Pakistan, the exclusion of direct sunshine is important in the summer months but, in the winter, sunshine in the teaching spaces provides an important source of heat to supplement that of the classroom stove.

2. See references 1-6 (page 30).

SUNSHADING DEVICES: SOME CONSIDERATIONS

1. Early consideration of the solar problem

It is important that sunshading calculations be made early in the design stage as, at this stage, the orientation, the type of construction, the lay-out, and the cost of construction of the building can still be adjusted.

2. Various types of sunshading devices

a) The roof overhang - for high sun (Figure 1)

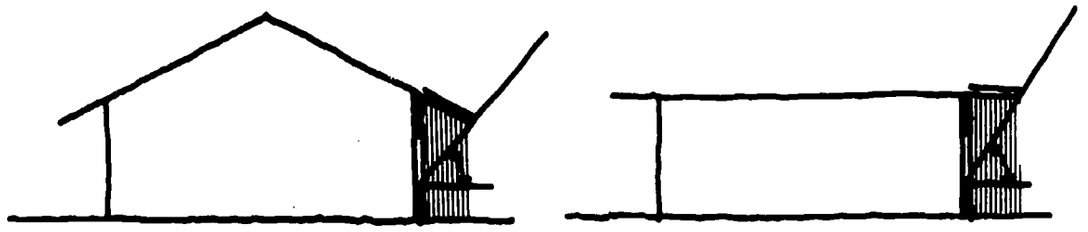

Figure 1.

b) The roof overhang with additional horizontal louvres - for low sun (Figure 2)

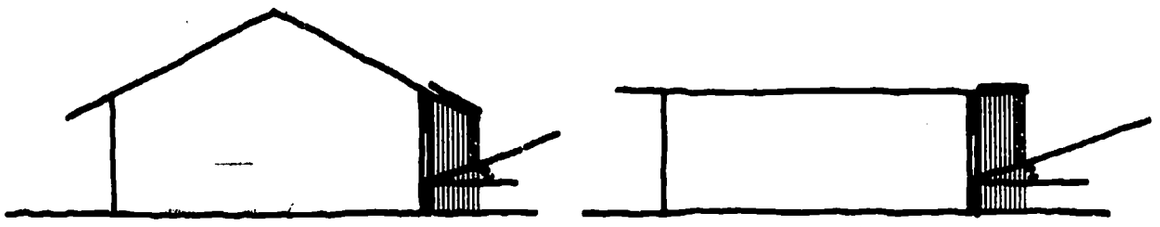

Figure 2.

c) The roof overhang with small, high-level windows - for low sun (Figure 3)

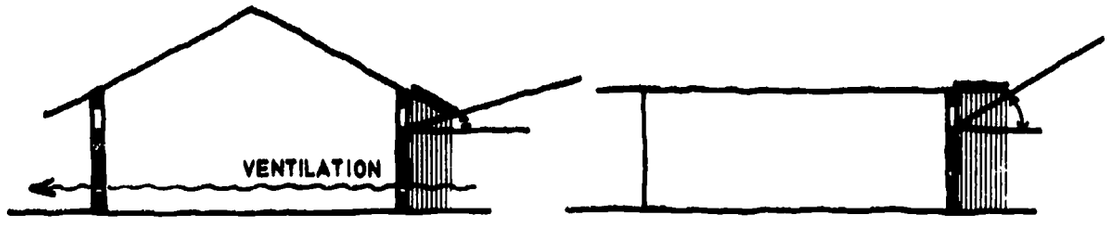

Figure 3.

d) Sunshading devices just above the window - for low sun (Figure 4). For heat reflection see para. 6, p. 11; for sound reflection see para. 7, p. 12.

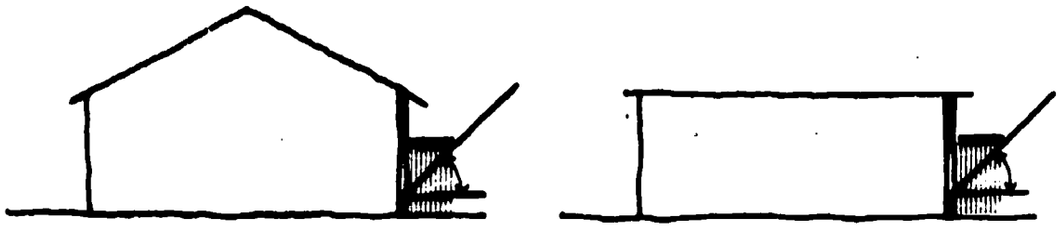

Figure 4.

e) Louvre-type, adjustable shutters (Figure 5)

- can be adjusted to almost any sun-angle
- can be adjusted to illumination requirements (see para. 5, p. 11)
- can be closed against rain, dust and illegal entry
- for effective sunshading, shutters should be almost continuous along the length of the building (Figure 14).

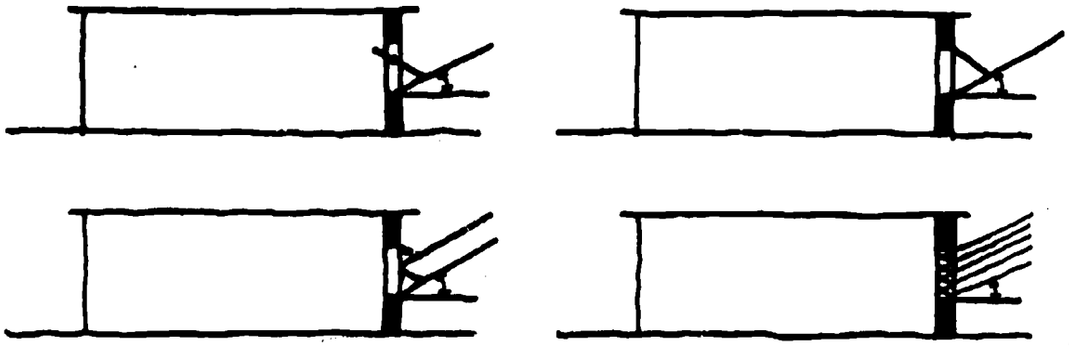

Figure 5.

f) Fixed louvres, grills etc, in brick, timber, concrete blocks etc. (Figure 6)

- inexpensive
- reasonable illumination possible
- good ventilation
- no illegal entry

(but - some rain, or dust may penetrate).

Figure 6

g) Shading by environment, e.g. building and trees (Figure 7).

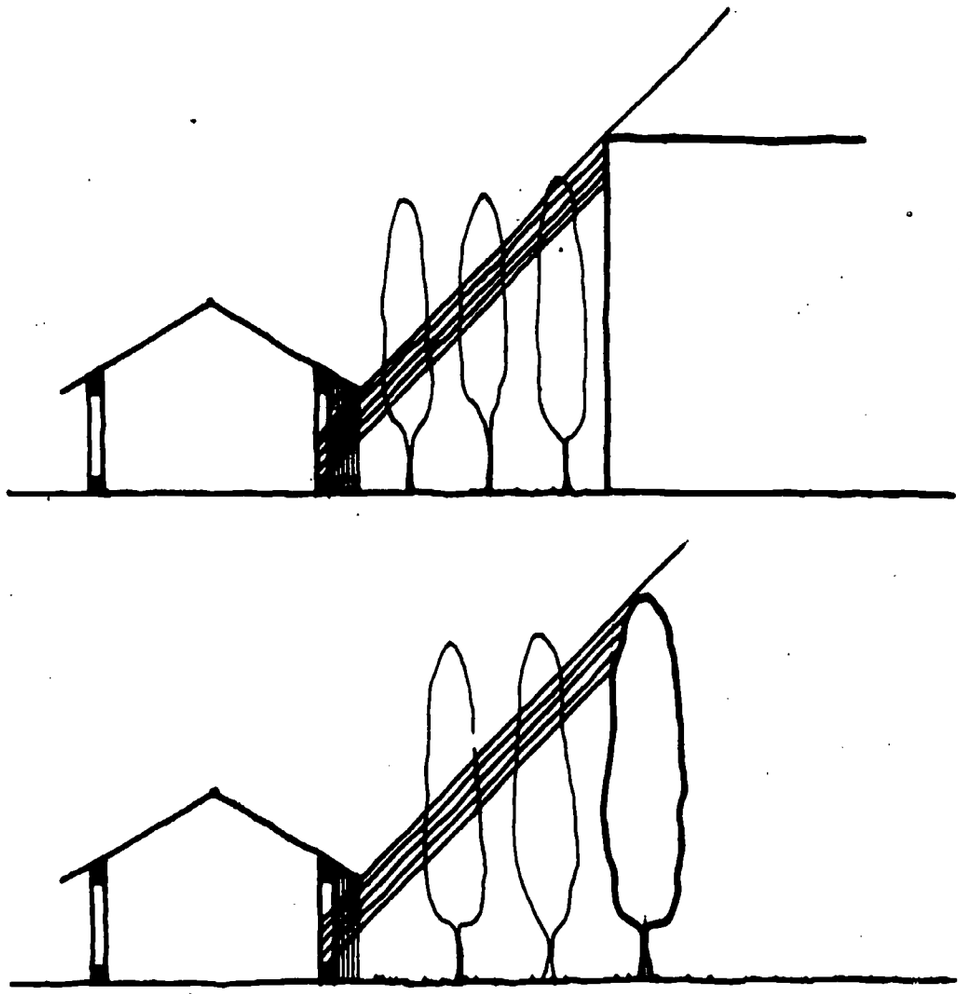

Figure 7.

3. Orientation, prevailing wind direction, limited site and sunshading

A good orientation of the building for economic sunshading, is with its longitudinal axis east-west, or with the window-walls facing north and south. For a comfortable thermal environment in the hot humid tropics, however, there is another consideration. Maximum ventilation will be obtained when the window-wall faces the prevailing wind direction (the prevailing wind in the hot season is of especial importance). The prevailing wind direction may result in a different orientation of the building from that most suitable for economic sunshading (i.e. major axis east-west). A compromise solution will give the most comfortable results. (Figure 8) A small site may impose other limitations for orientation. Adaptation of sunshades will then be necessary. In many countries standard school building designs with standard sunshades are used. However, prevailing wind directions in the hot season, may be different for different locations in a country. Small sites, coupled with limited understanding of sunshading on the part of the construction supervisor, or unreasonable prejudices such as, those requiring 'buildings to be parallel to the road', may be reasons for a different orientation than was anticipated in the design of the standard school building.

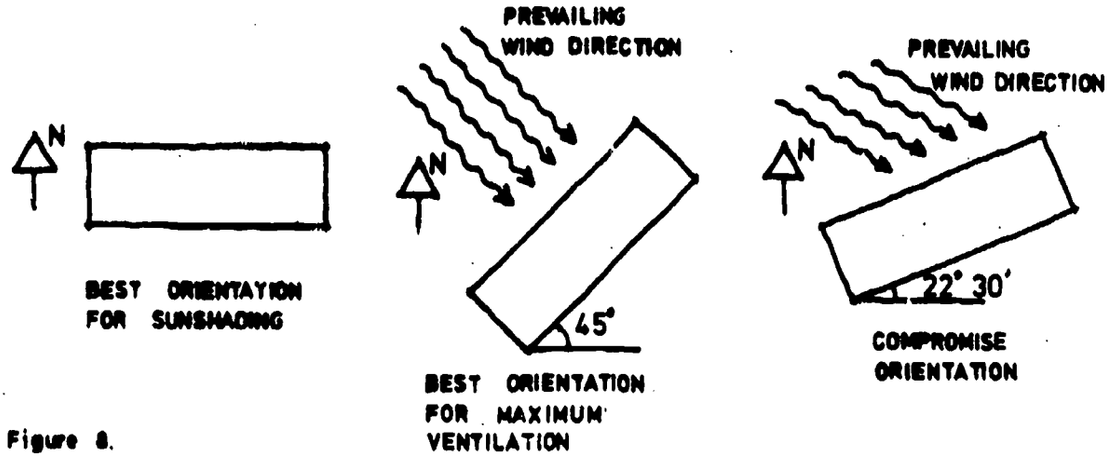

Figure 8.

The lack of firm directives for orientation of the school building is one of the main reasons for the ineffectiveness of costly sunshading devices in a great number of school buildings. All drawings for schools in the tropics should have the required orientation very clearly marked on them.

4. Driving rain, dust, illegal entry

Louvres and adjustable shutters are effective sunshading devices, and they also can be closed in times of rain- and dust-storms. The illumination level will drop considerably, however, when shutters are closed (shutters can also prevent vandals from entering the building through the windows). The orientation of the building at which the windows face the prevailing wind direction in the rainy or dusty season might thus be one to be avoided.

5. The minimum window surface

As windows and sunshading devices are usually expensive, careful consideration should be given to the minimum surface of the window required to provide:

a) The required illumination level * (white-washing of walls, ceilings and shutters is an inexpensive means of increasing the illumination level).

b) Required airspeed (ventilation) at body level (special ventilation openings at body level will improve thermal comfort).

6. Heat reflection

Solid sunshades are likely to reflect radiant heat into the building. This can be avoided by using louvred sunshading, as shown comparatively in Figures 9 and 10 (on page 12).

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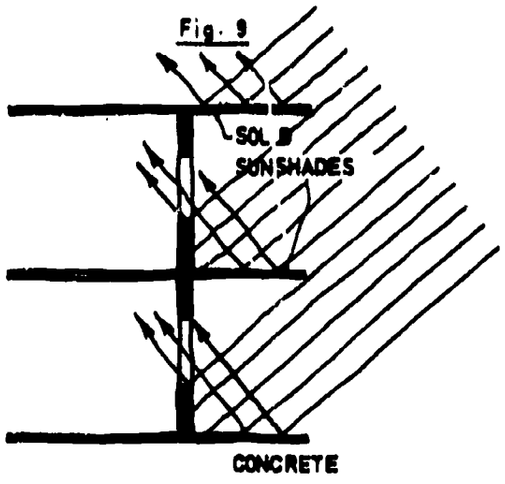
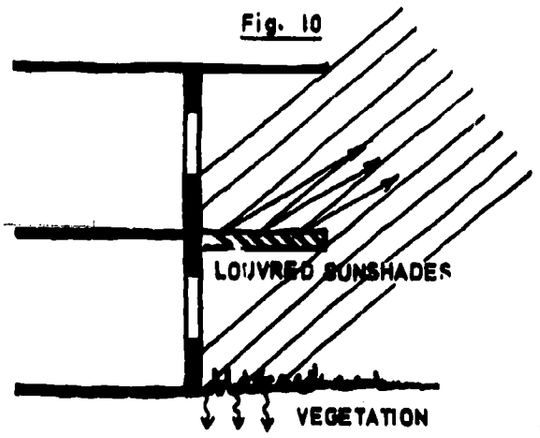
* See references 7-12 (page 30).

Fig. 9



SOLID SUNSHADING DEVICE AND PAVING REFLECT RADIANT HEAT INTO THE BUILDING.

Fig. 10

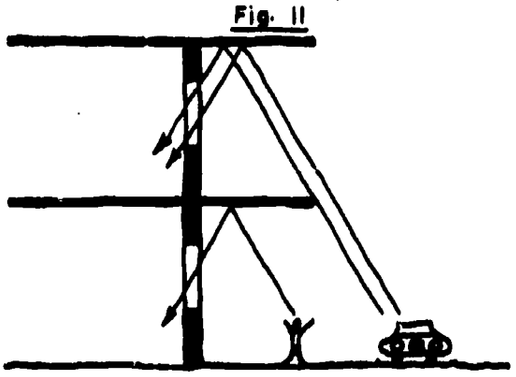


LOUVRED SUNSHADING DEVICE AND VEGETATION REFLECT RADIANT HEAT AWAY FROM THE BUILDING, OR ABSORB IT.

7. Sound reflection

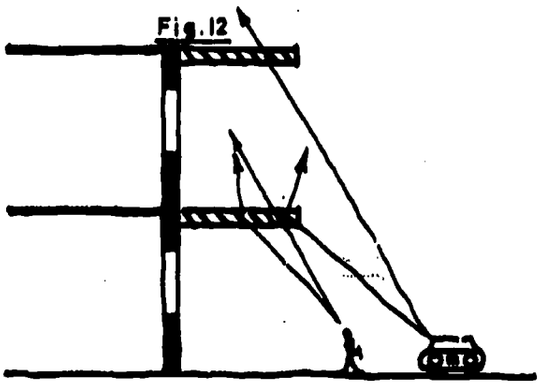
Solid sunshades also may reflect sound into the building (Figure 11). This can also be avoided with the same louvred sunshades, as shown in Figure 12.

Fig. 11



MOST SOUND IS REFLECTED INTO THE BUILDING.

Fig. 12



MOST SOUND IS REFLECTED AWAY FROM THE BUILDING.

8. Reducing heat load on teaching spaces by planning

Spaces which people do not frequently use should be located on east and west walls, where they will have a heat insulating function (Figure 13).

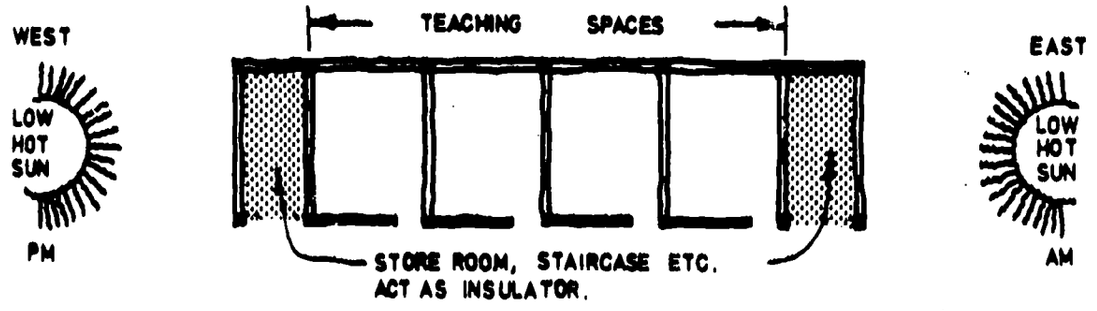


Figure 13.

The scope of this publication is limited to the following conditions:

1. Only vertical, projected sun-angles are given (see explanation, p. 16).
2. Only continuous, horizontally directed sunshades can be determined (Figure 14).
3. For a totally effective sunshade, end walls should be extended fully under the sunshade (Figures 14 and 15).

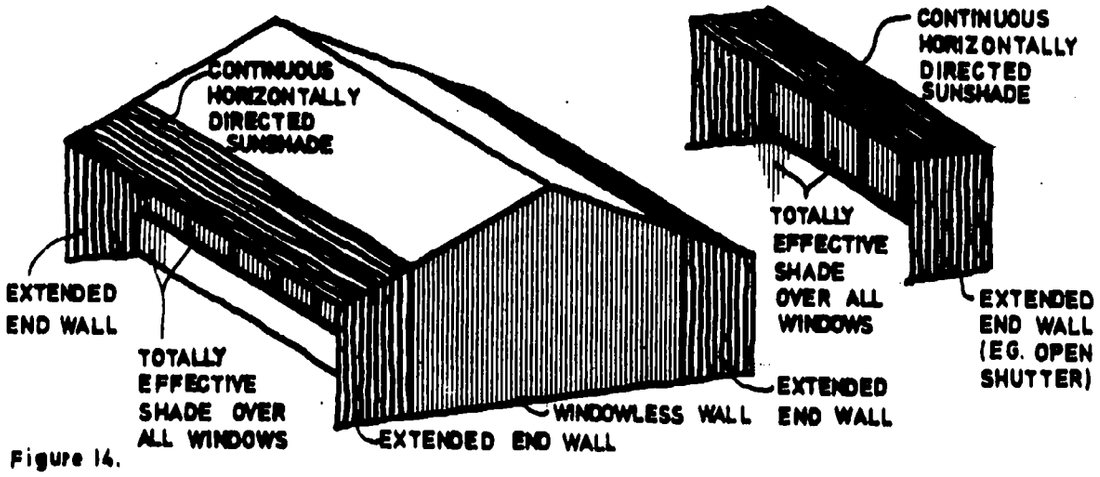


Figure 14.

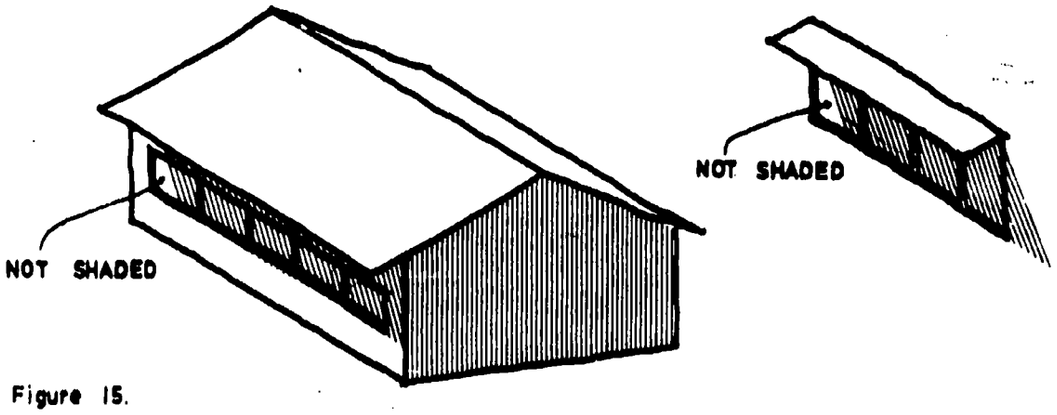


Figure 15.

If extension of end walls is impossible, undesired or unnecessary, as for example in Figures 13 and 16, where the sunshade extends beyond the windows, one of the references * should be consulted to design the sunshade.

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* See references 1-6 (page 30).

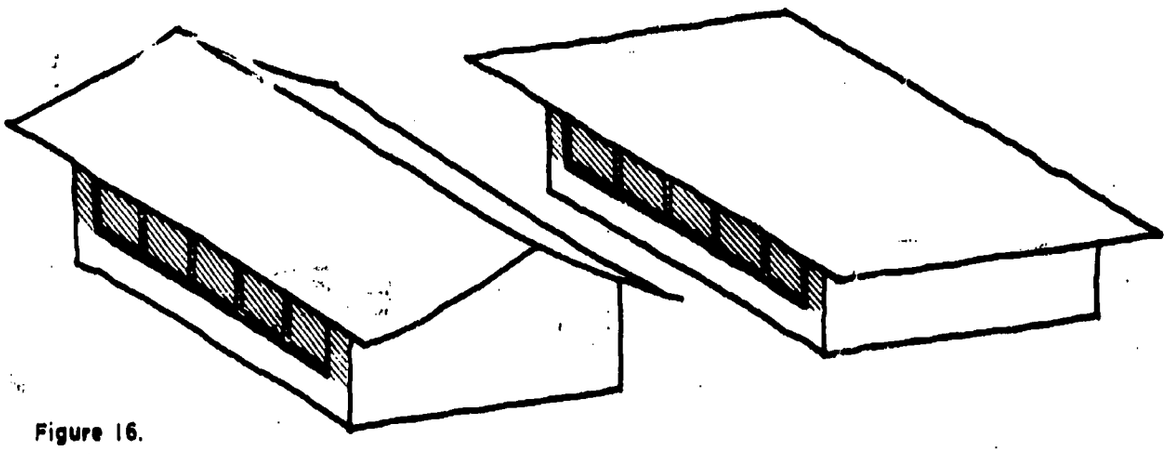


Figure 16.

4. The data given can be used to design sunshades to exclude sunshine during the school day (8.00 a.m. - 4.00 p.m.). Before 8.00 a.m. and after 4.00 p.m., direct sunshine may penetrate into the building. Direct sunshine at, say, 7.00 a.m. will not be disastrous, as the sun is low and it will still be cool. Direct sunshine at 5.00 p.m. in the case of a double-shift school however, could be troublesome. In this case again, references* should be consulted to design the sunshading devices.

5. The data given can be used for the countries of the Asian region which lie between the latitudes 10° south and 32° north. For higher and lower latitudes, references * should be consulted to design the sunshading devices.

6. The sun-angles are given for the even latitudes only. Interpolation gives sufficiently accurate sun-angles for odd latitudes.

7. The sun-angles are given for orientations of the longitudinal axis of the building E-W, NE-SW, NW-SE, WSW-ENE and WNW-ESE. Interpolation will give the sun-angles for other orientations.

THE SUNPATH

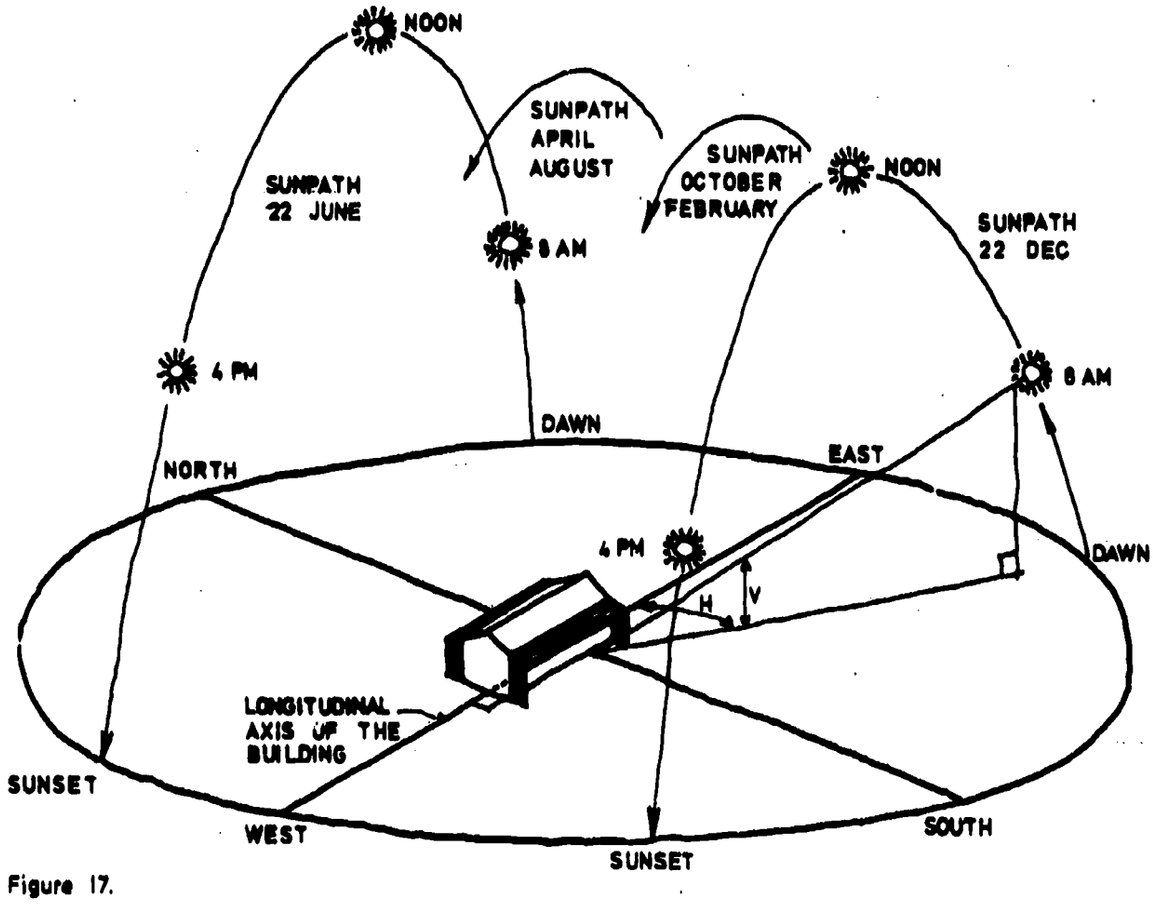


Figure 17.

Direct sunshine should be kept out of the building during the school day, which has been assumed to start at 8.00 a.m. and to finish at 4.00 p.m. If the sunshades are designed to exclude the sun on 22 June and December, during the school day, then they should be large enough to exclude sun during all other school days of the year (Figure 17). Two angles may thus be of consequence, V and H. The horizontal angle H is only of importance in complex cases, however, and will not be considered here. If this angle is significant, one of the references * should be consulted.

---

* See references 1-6 (page 30).

THE SUNSHADING DIAGRAMS EXPLAINED

For the sunshading diagrams, see pages 19 through 29. The first column of the diagrams refers to the orientation of the building. For quick determination of the extent of sunshading required to keep the sun out of the building during the critical hours between 8.00 a.m. and 4.00 p.m., the actual vertical sun-angles (V_1), have been projected on to a plane, section A-B, perpendicular to the longitudinal axis of the building (V_2) (Figures 17, 18 and 19).

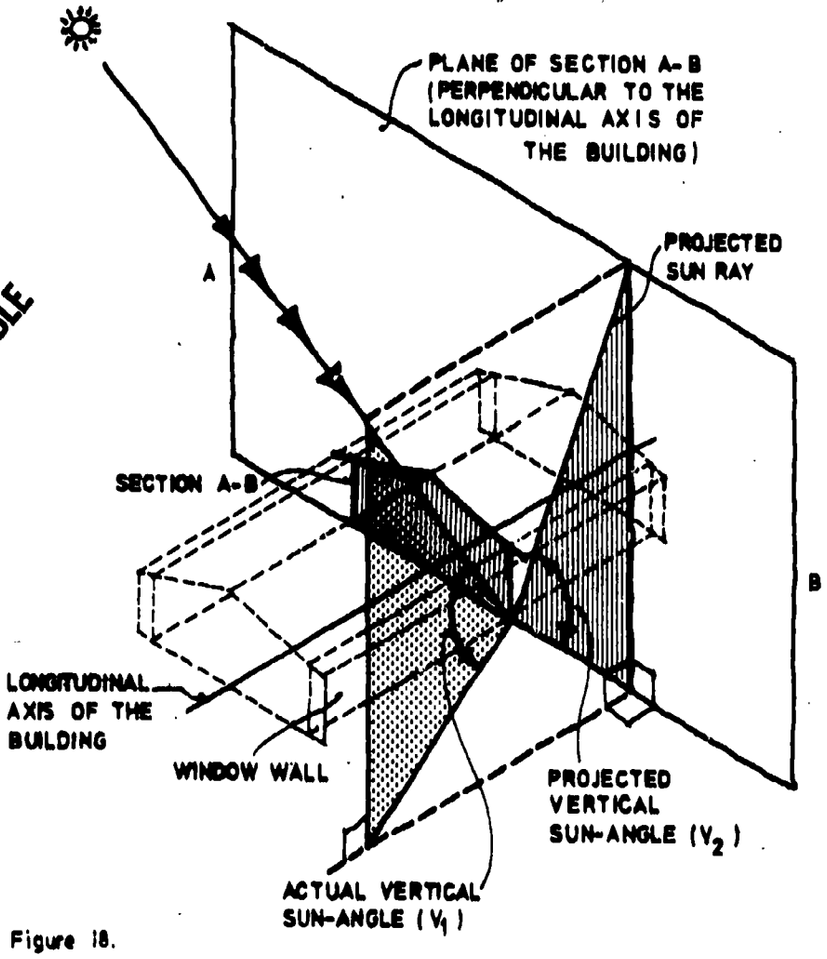


Figure 18.

The projected vertical sun-angles V_2 given in the columns 2 and 3 of the sunshading diagrams for the critical hours and dates; for the different orientations of the longitudinal axis of the building, and thus for different orientations of the section A-B, can directly be utilized for the determination of the extend of sunshade required (Figure 19).

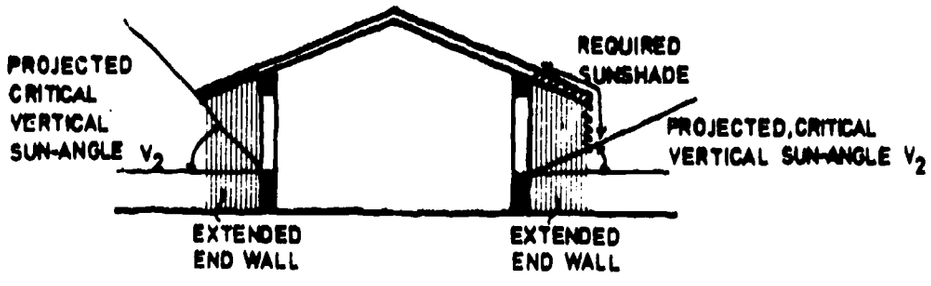


Figure 19. SECTION A - B

1. Required. To determine the orientation and the extent of sunshading required for the building shown in Figure 20.

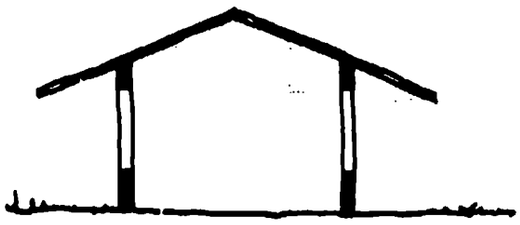


Figure 20

Conditions. Hot humid climate. Latitude 13° N.
Prevailing wind direction in hot season SW.

Possible solution. Orientation, see Figure 21.

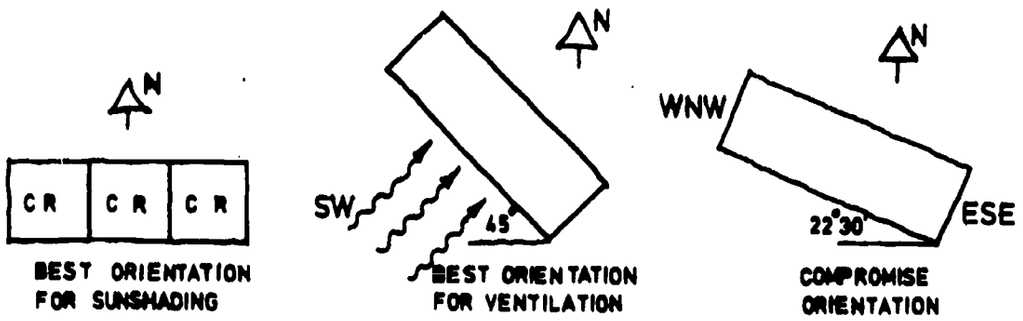


Figure 21

Interpolation between 12°N and 14°N for the orientation WNW-ESE gives the required critical angles (Figure 22).

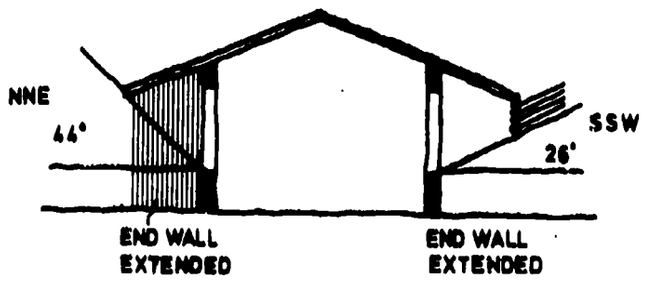


Figure 22.

2. Required. To determine the orientation of the building and the extent of sunshading required, for the building shown in Figure 23. There should be no heat radiation and as little as possible noise reflection into the building. Thermal comfort should be improved by natural ventilation.

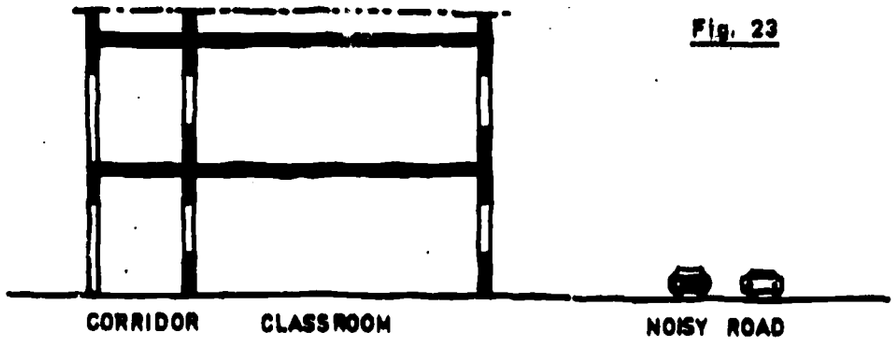


Fig. 23

Conditions. Latitude 2° S. Hot humid climate. Prevailing wind direction during hot season SE.

Possible solution. See Figures 24 and 25.

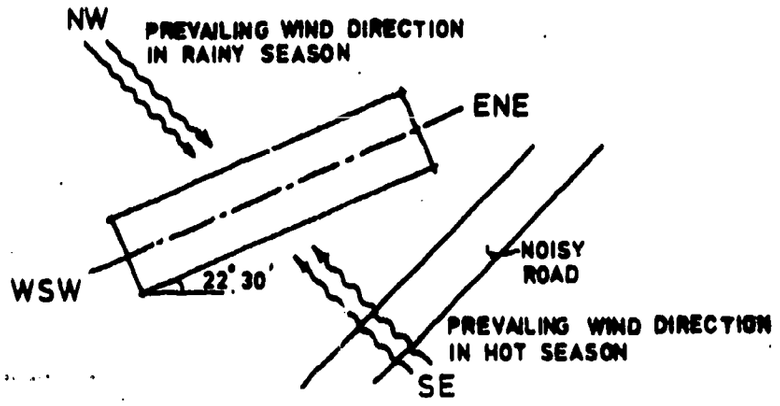


Figure 24.

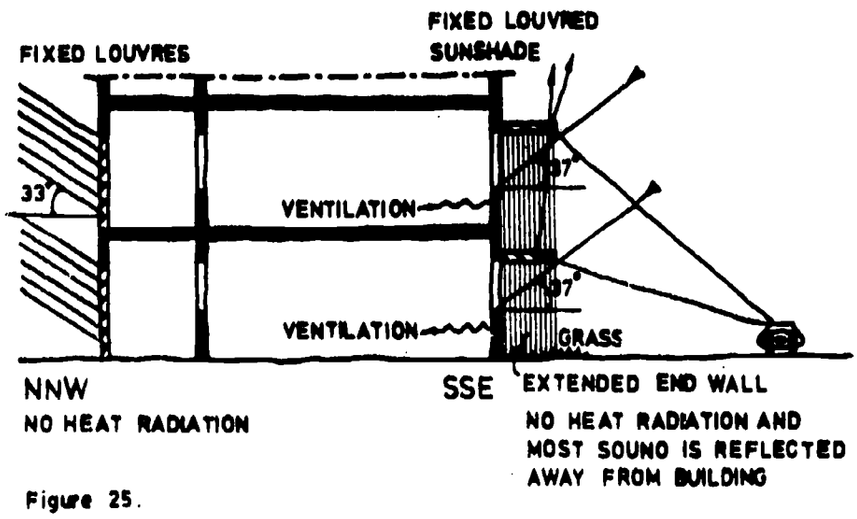
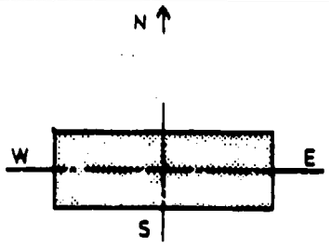
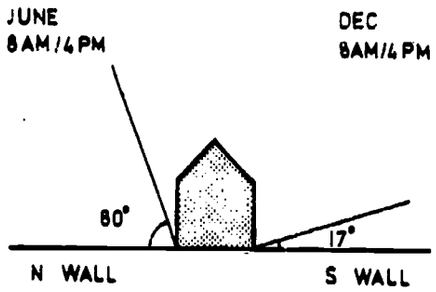
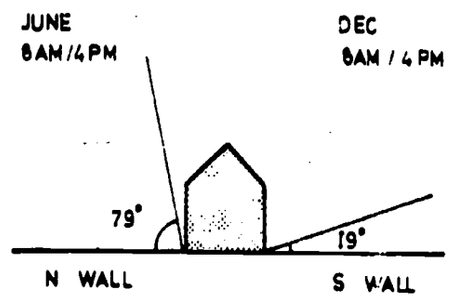
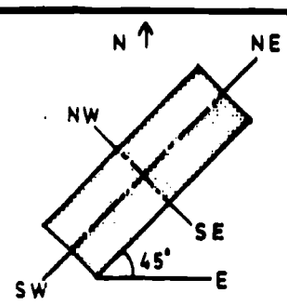
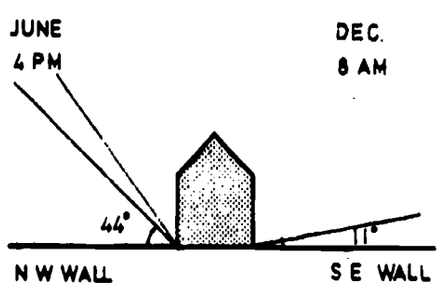
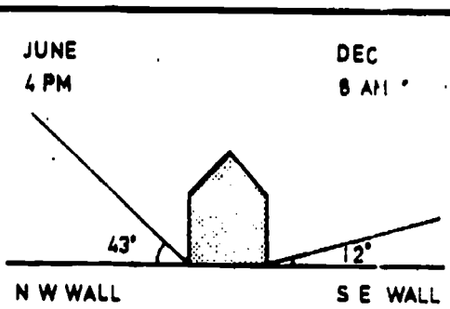
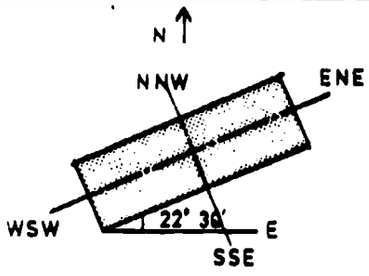
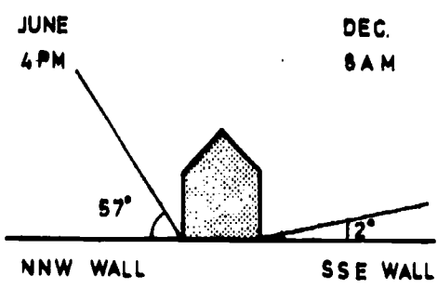
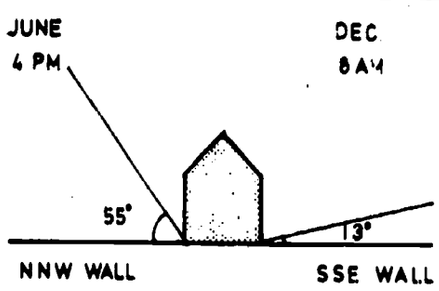
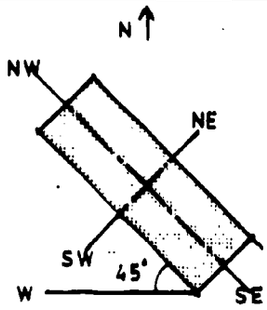
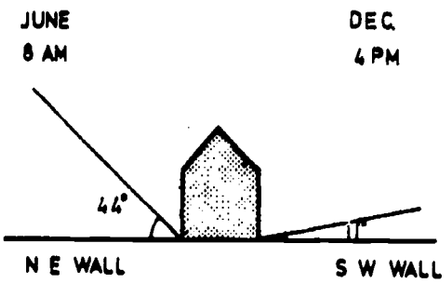
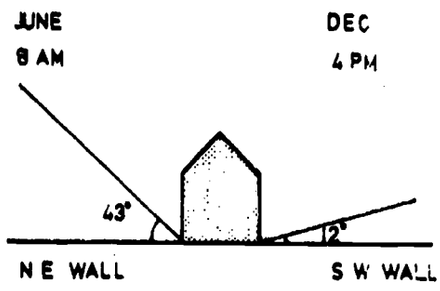
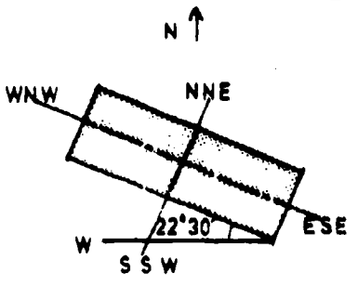
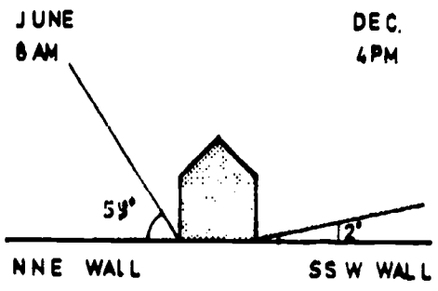
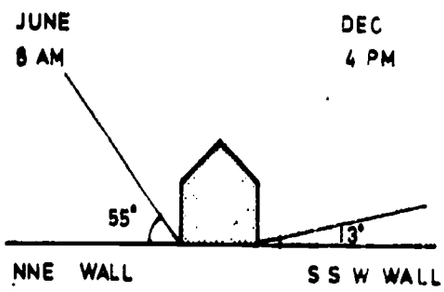
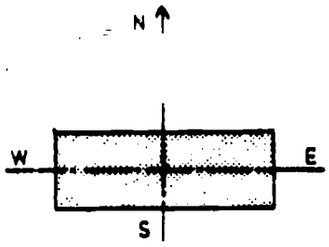
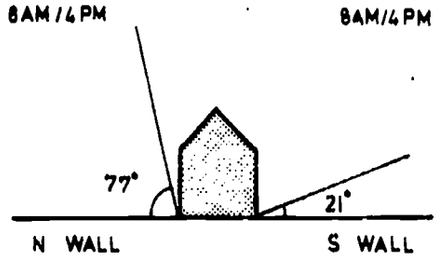
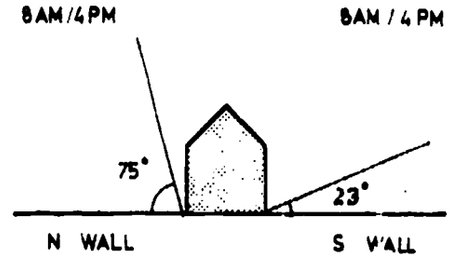
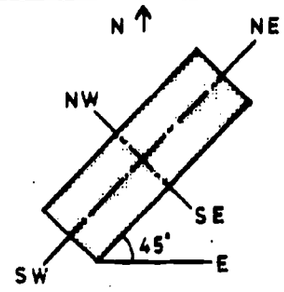
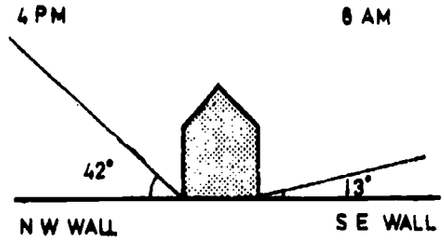
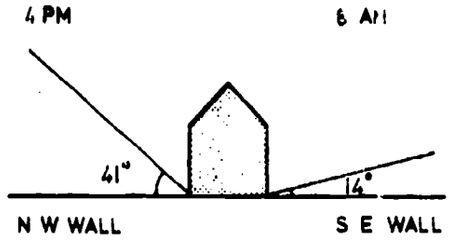
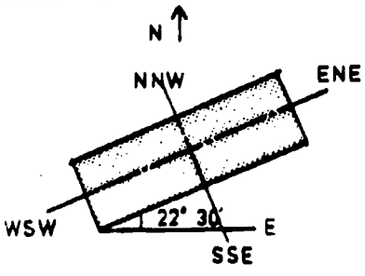
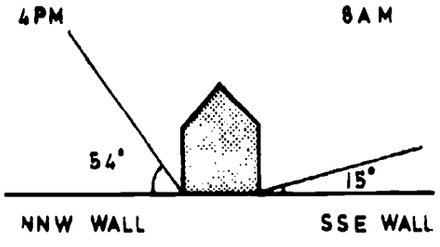
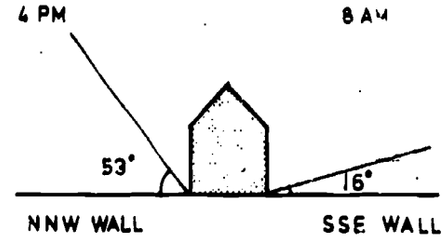
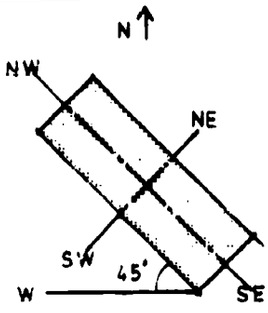
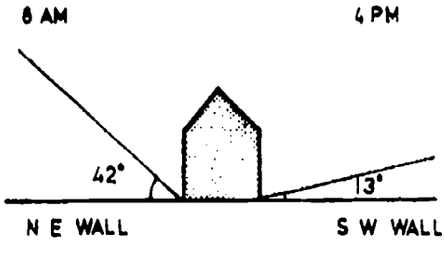
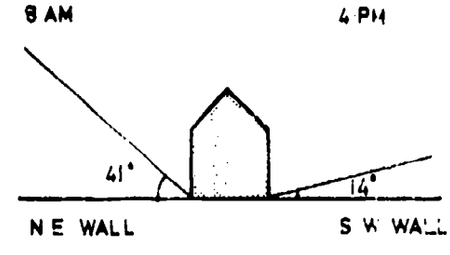
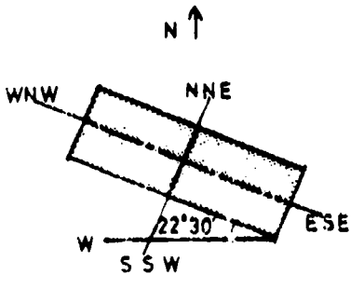
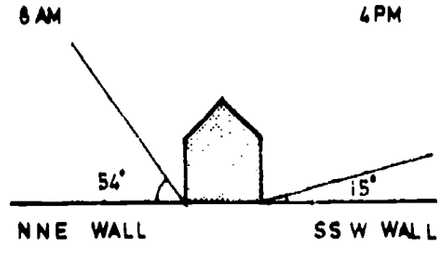
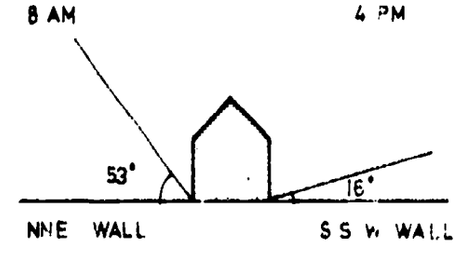


Figure 25.

SUN SHADING DIAGRAM

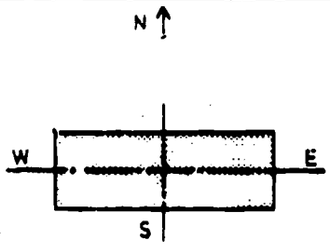
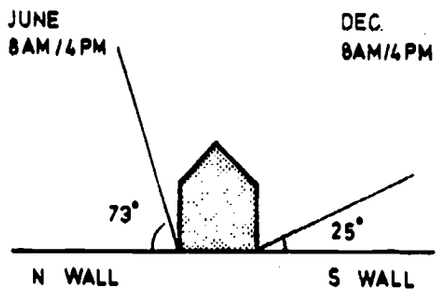
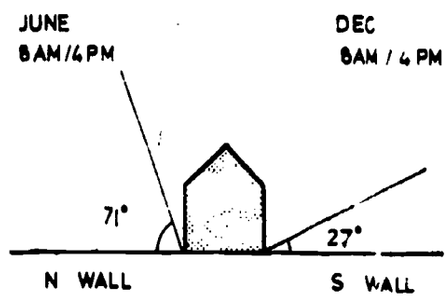
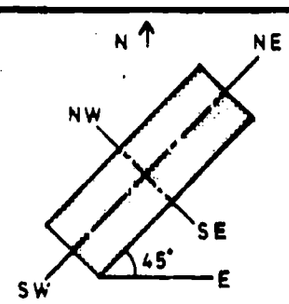
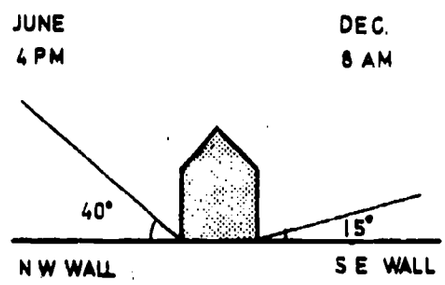
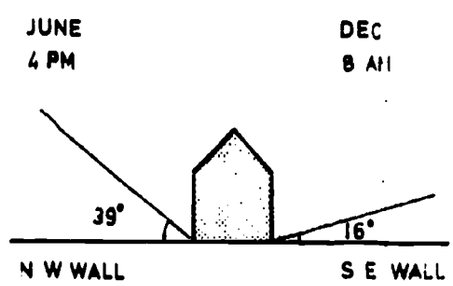
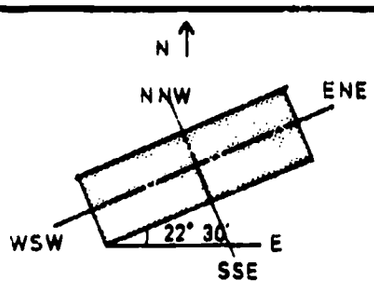
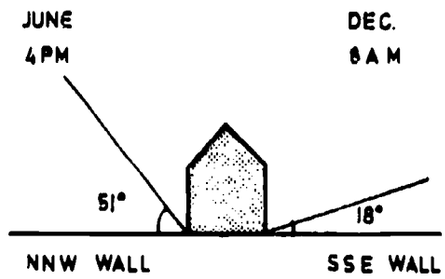
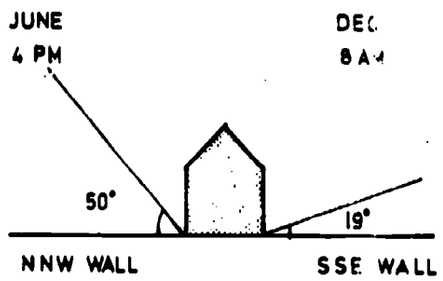
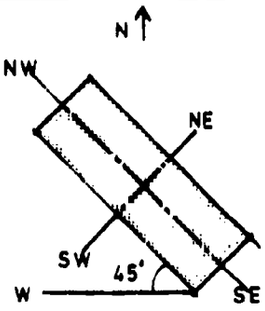
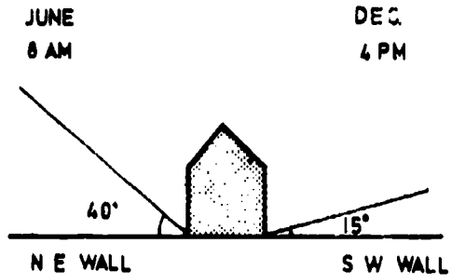
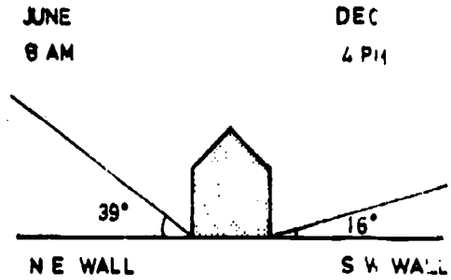
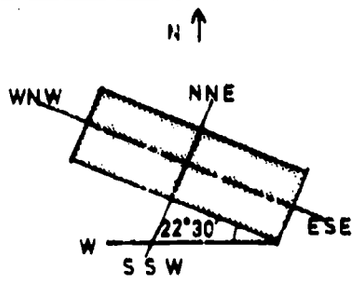
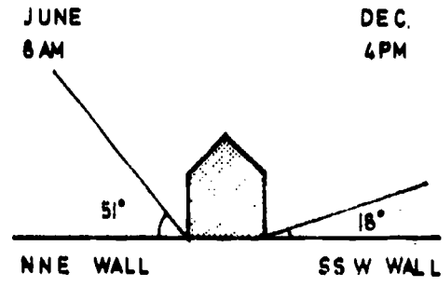
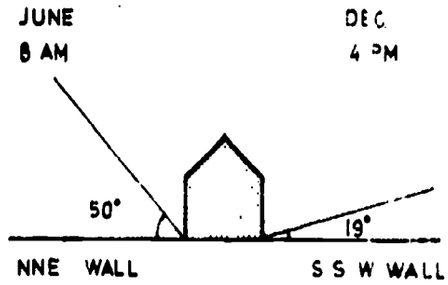
CRITICAL VERTICAL SUN ANGLES DURING THE SCHOOL DAY 8 AM - 4 PM PROJECTED ON THE PLANE OF SECTION A - B

ORIENTATION	LATITUDE 32°N SECTION A - B	LATITUDE 30°N SECTION A - B
		
		
		
		
		

SUN SHADING DIAGRAM	CRITICAL VERTICAL SUN ANGLES DURING THE SCHOOL DAY 8 AM - 4 PM PROJECTED ON THE PLANE OF SECTION A - B	
ORIENTATION	LATITUDE **28° N**	LATITUDE **26° N**
	SECTION A - B	SECTION A - B
		
		
		
		
		

SUN SHADING DIAGRAM

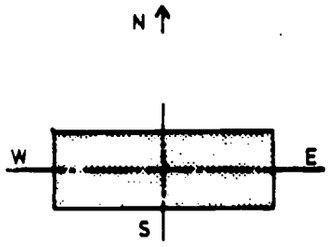
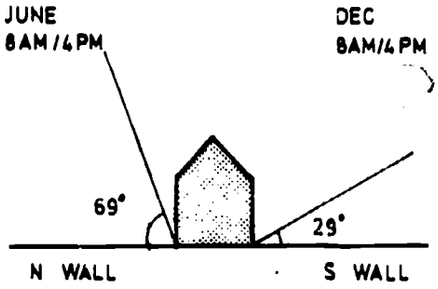
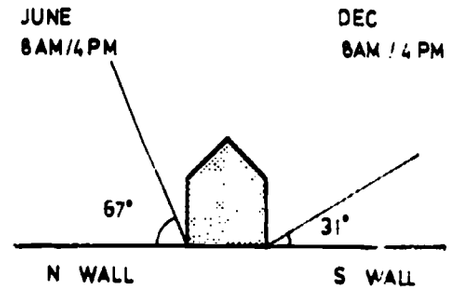
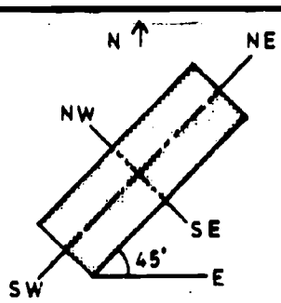
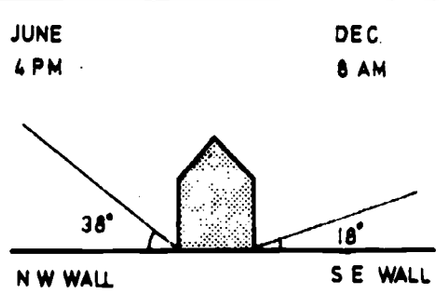
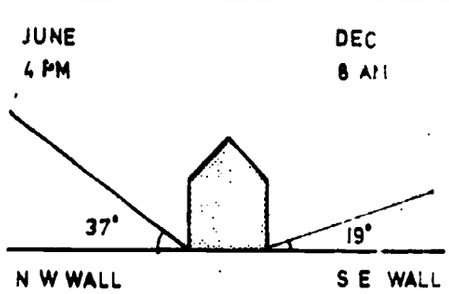
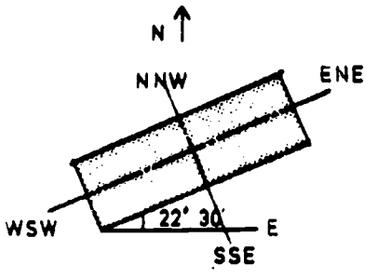
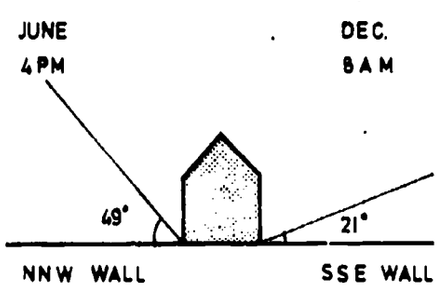
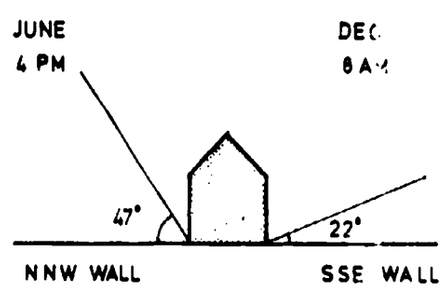
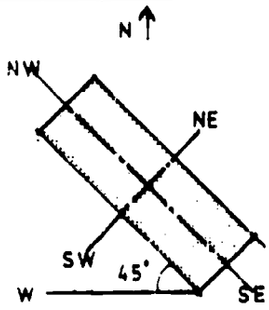
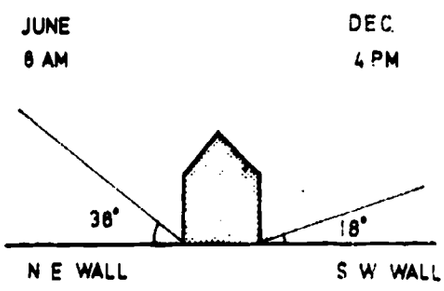
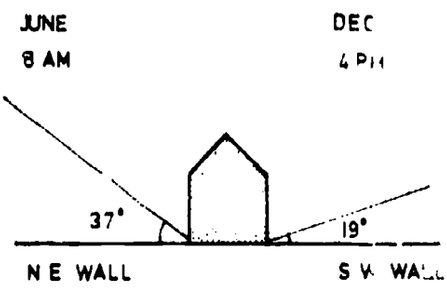
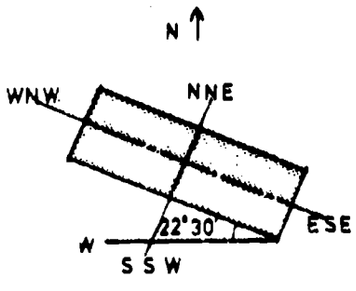
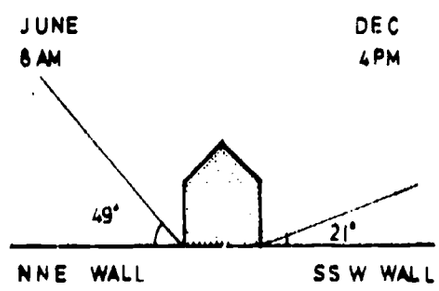
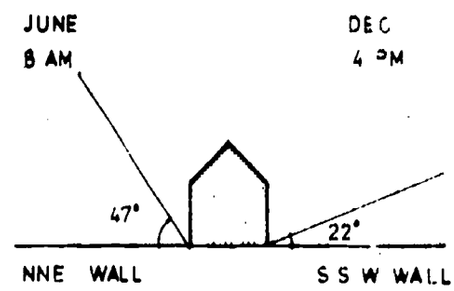
CRITICAL VERTICAL SUN ANGLES DURING THE SCHOOL DAY 8 AM - 4 PM PROJECTED ON THE PLANE OF SECTION A-B

ORIENTATION	LATITUDE 24°N SECTION A - B	LATITUDE 22°N SECTION A - B
		
		
		
		
		

BEST COPY AVAILABLE

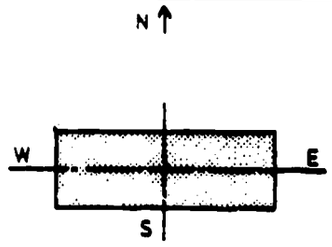
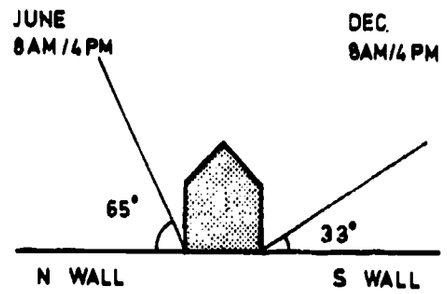
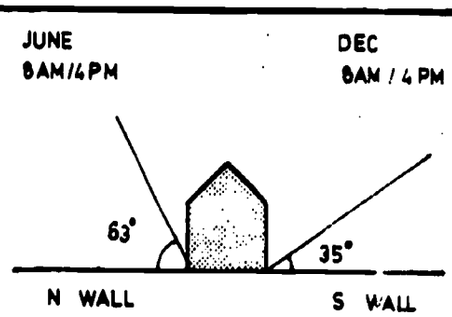
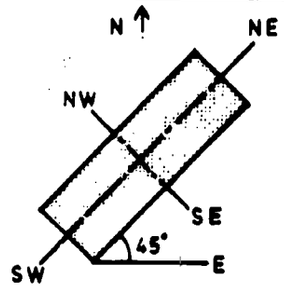
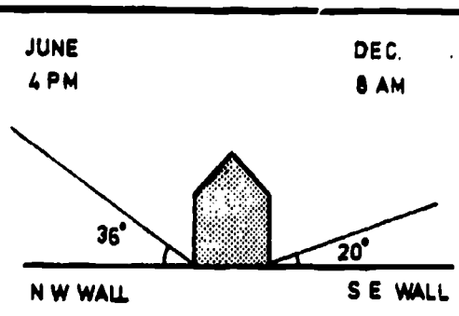
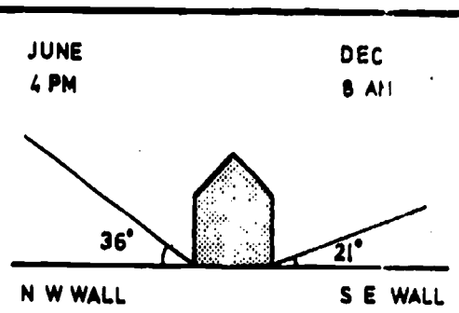
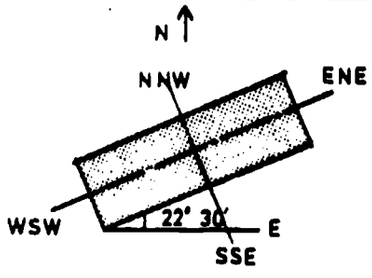
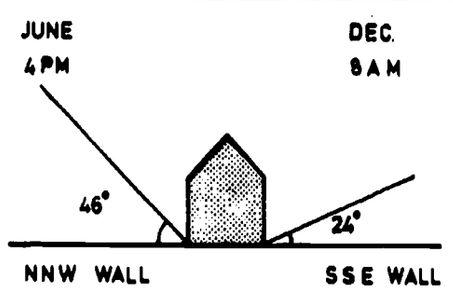
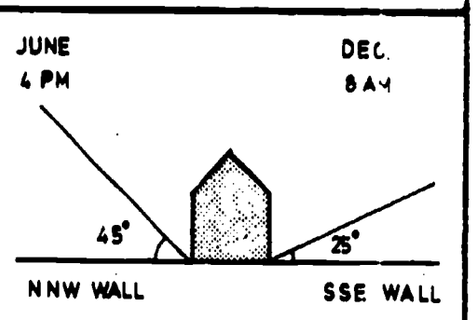
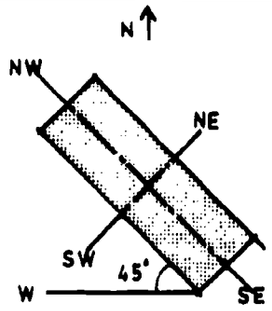
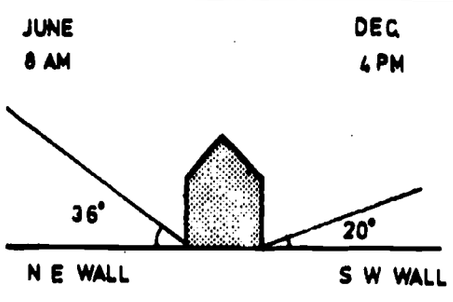
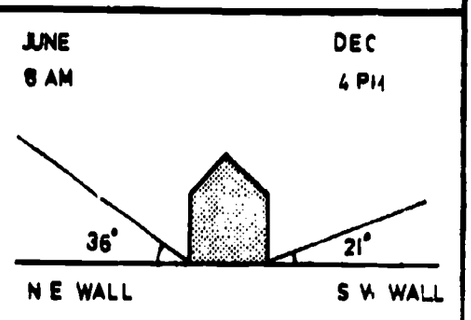
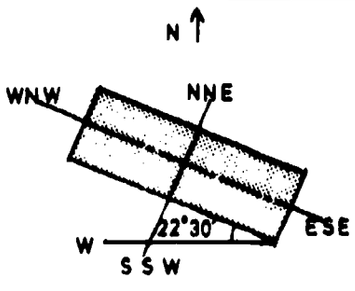
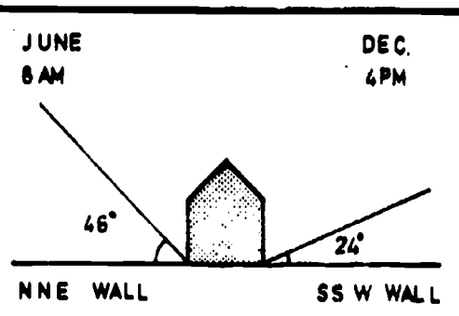
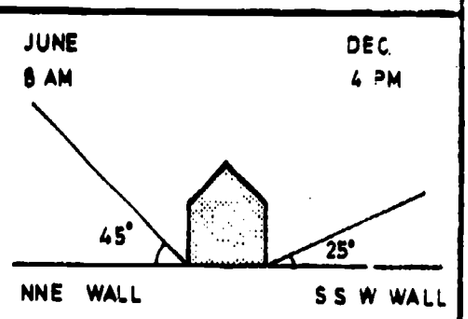
SUN SHADING DIAGRAM

CRITICAL VERTICAL SUN ANGLES
DURING THE SCHOOL DAY 8 AM - 4 PM
PROJECTED ON THE PLANE OF SECTION A - B

ORIENTATION	LATITUDE 20°N SECTION A - B	LATITUDE 18°N SECTION A - B
		
		
		
		
		

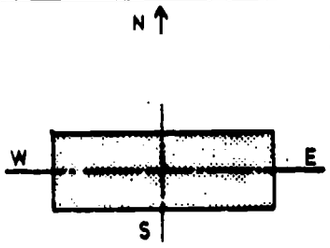
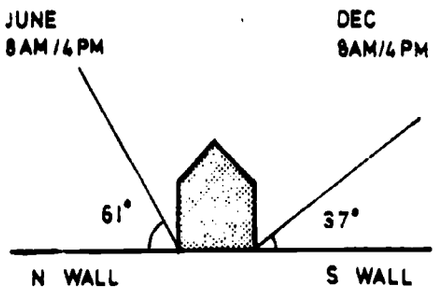
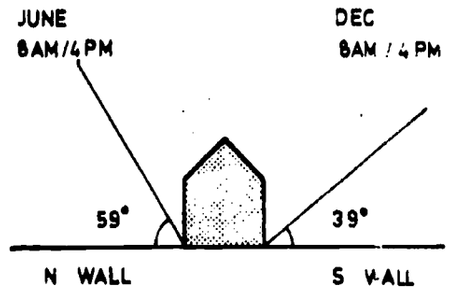
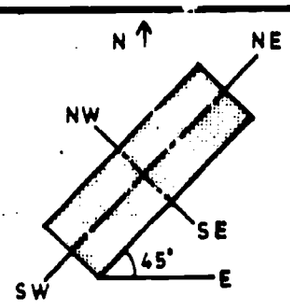
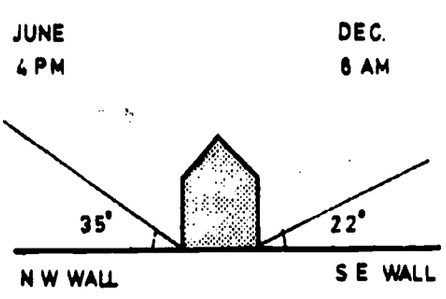
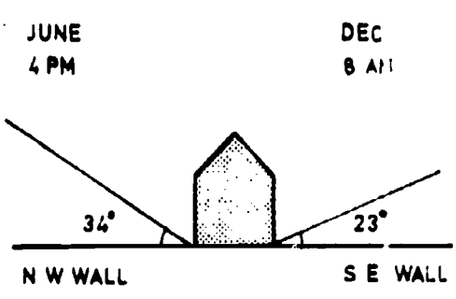
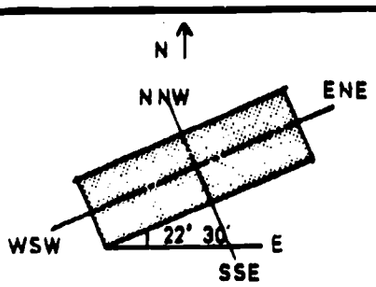
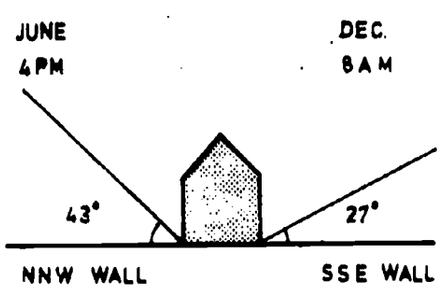
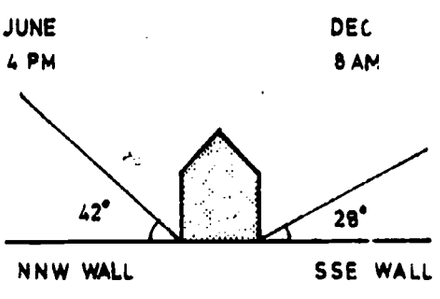
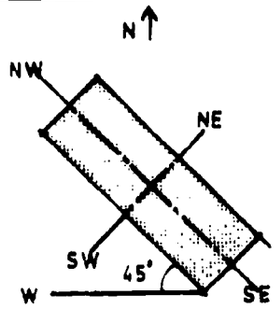
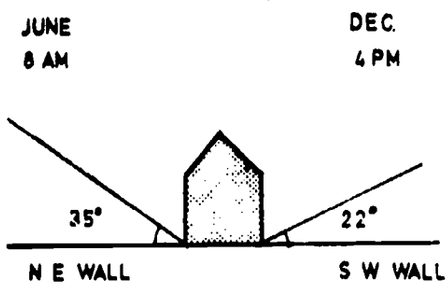
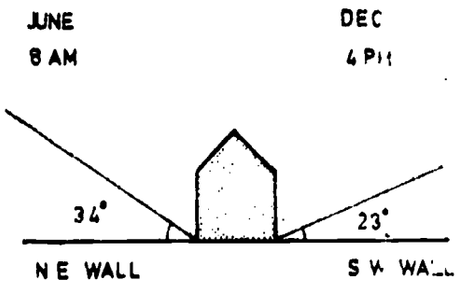
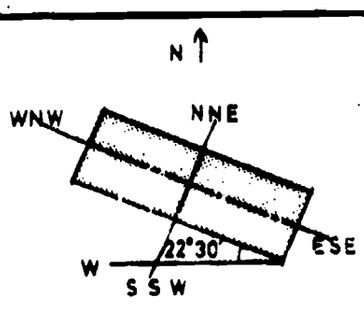
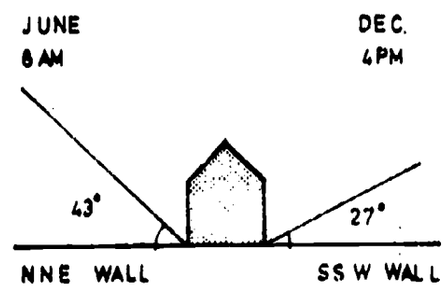
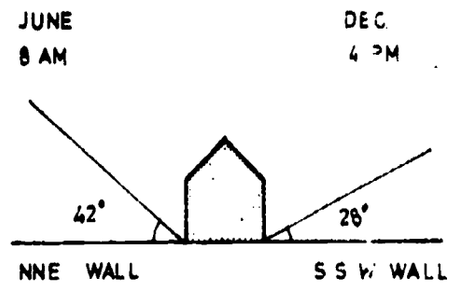
SUN SHADING DIAGRAM

CRITICAL VERTICAL SUN ANGLES DURING THE SCHOOL DAY 8 AM - 4 PM PROJECTED ON THE PLANE OF SECTION A - B

ORIENTATION	LATITUDE 16°N SECTION A - B	LATITUDE 14°N SECTION A - B
		
		
		
		
		

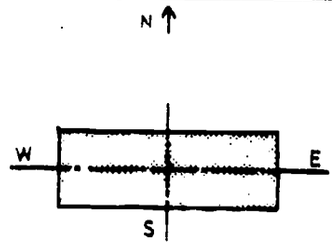
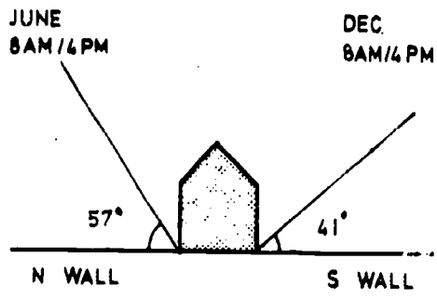
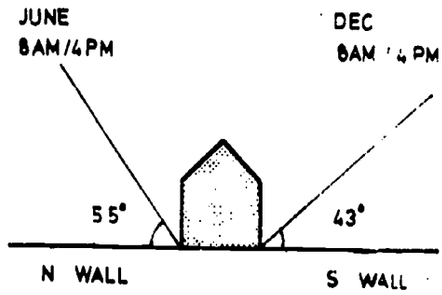
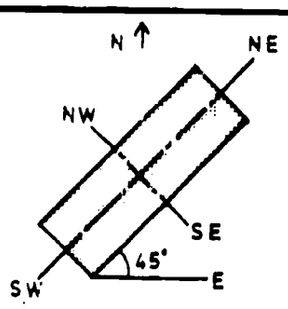
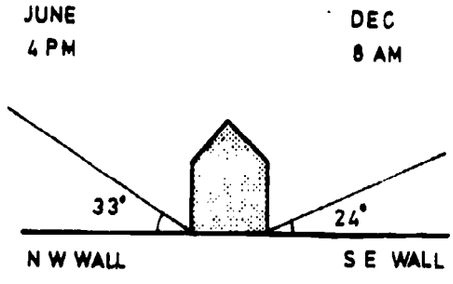
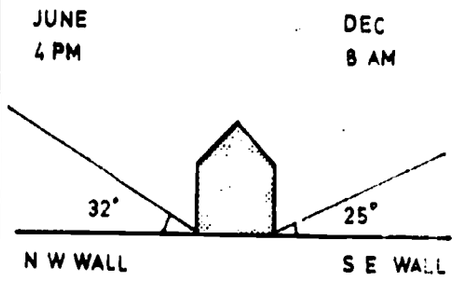
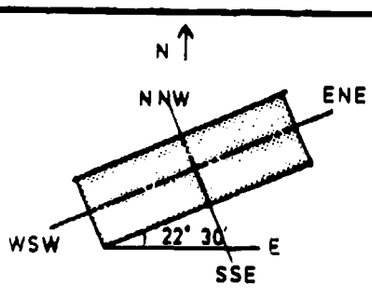
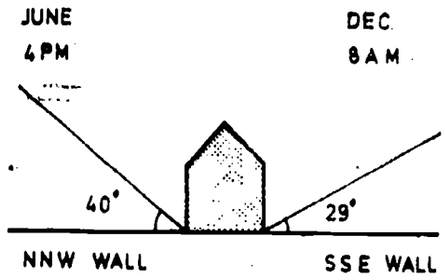
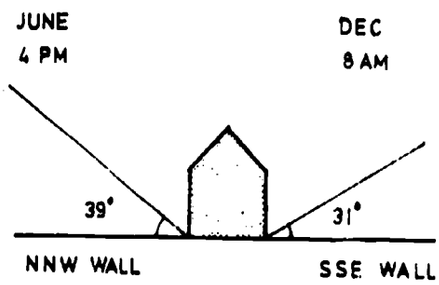
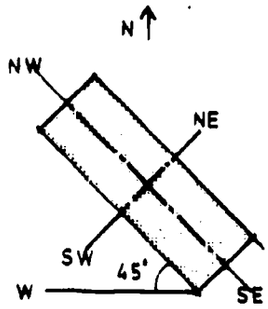
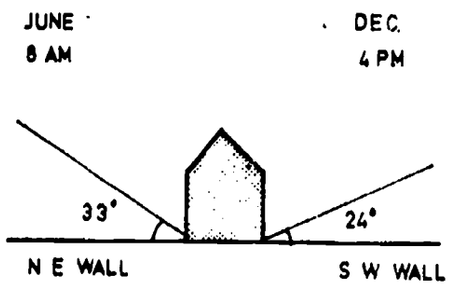
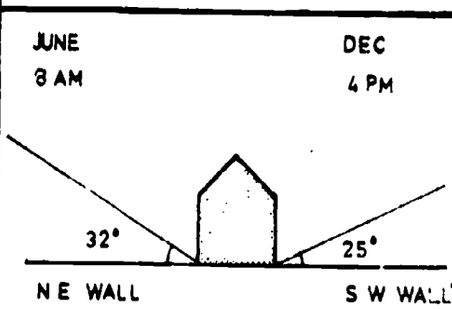
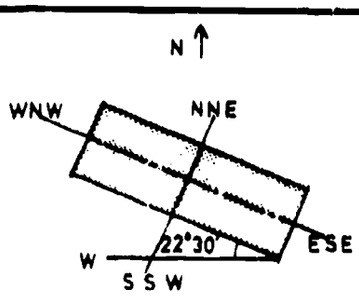
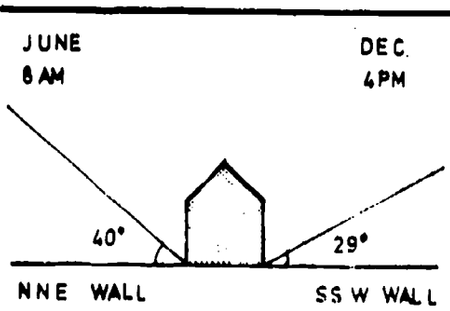
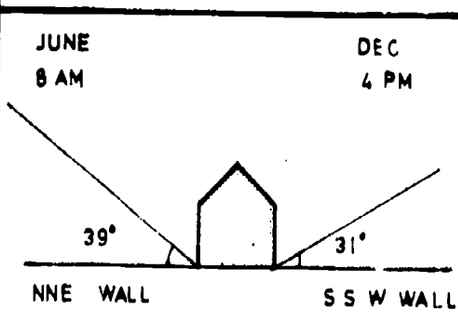
SUN SHADING DIAGRAM

CRITICAL VERTICAL SUN ANGLES
DURING THE SCHOOL DAY 8 AM - 4 PM
PROJECTED ON THE PLANE OF SECTION A - B

ORIENTATION	LATITUDE 12°N SECTION A - B	LATITUDE 10°N SECTION A - B
		
		
		
		
		

SUN SHADING DIAGRAM

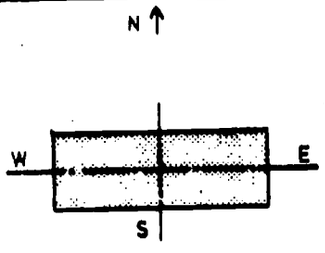
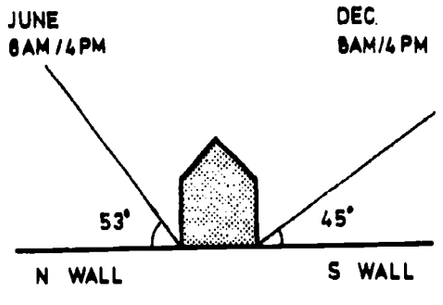
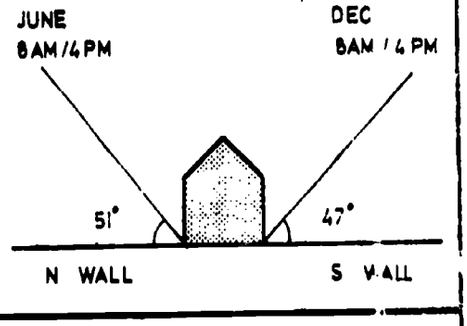
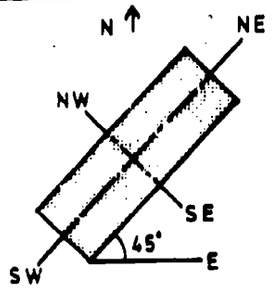
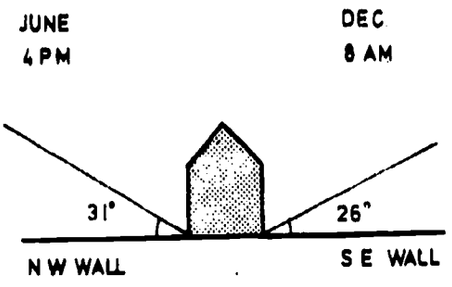
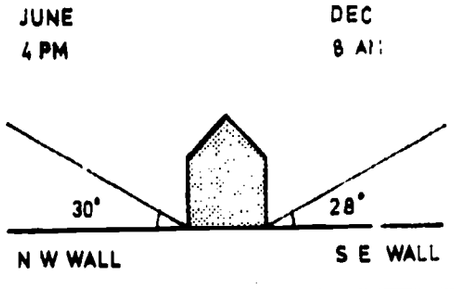
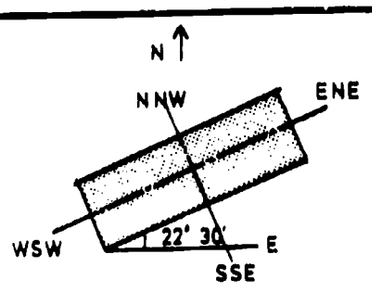
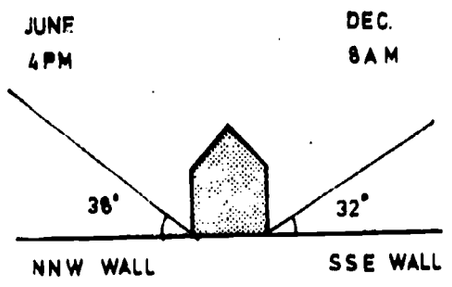
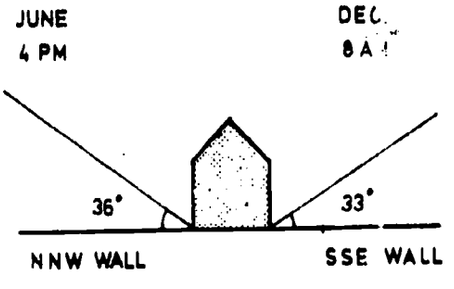
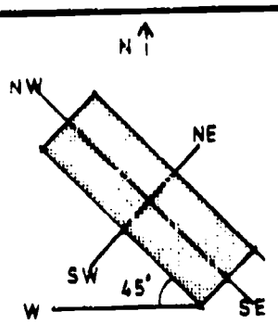
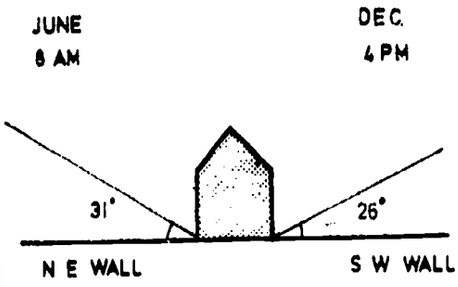
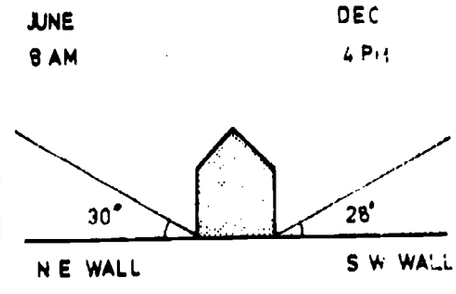
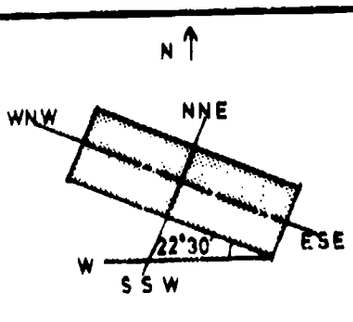
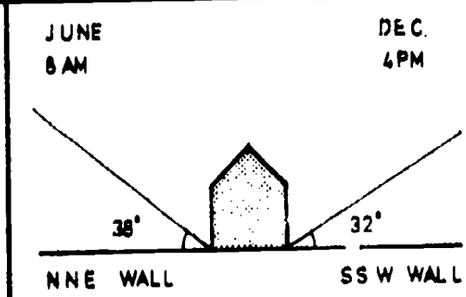
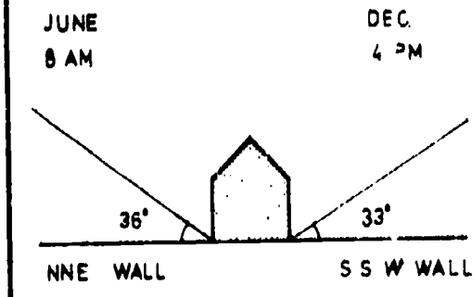
CRITICAL VERTICAL SUN ANGLES DURING THE SCHOOL DAY 8 AM - 4 PM PROJECTED ON THE PLANE OF SECTION A - B

ORIENTATION	LATITUDE 8° N SECTION A - B	LATITUDE 3° N SECTION A - B
		
		
		
		
		

BEST COPY AVAILABLE

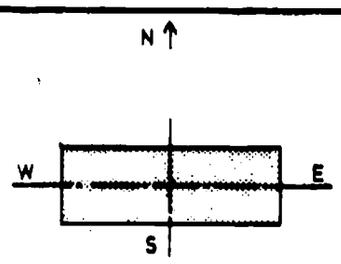
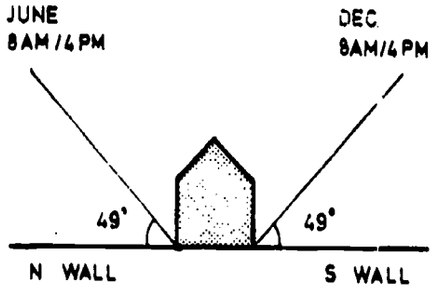
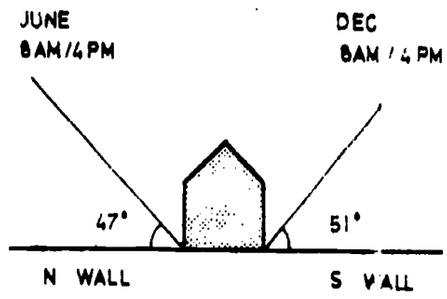
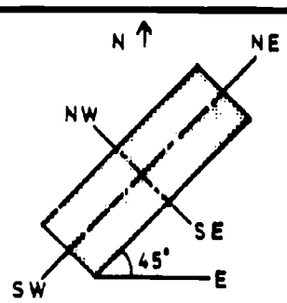
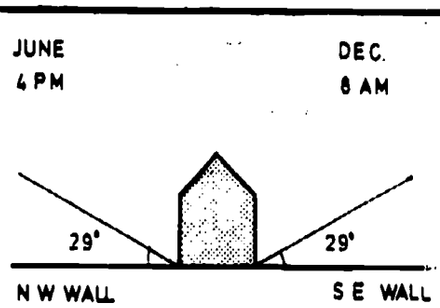
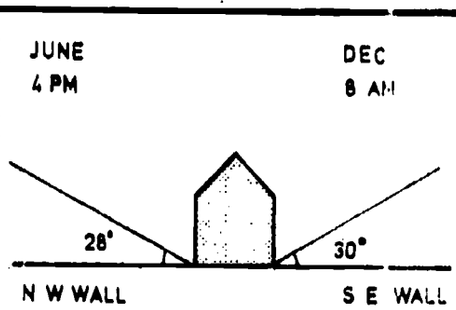
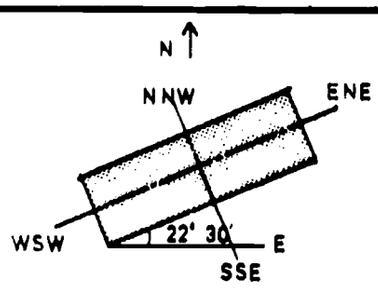
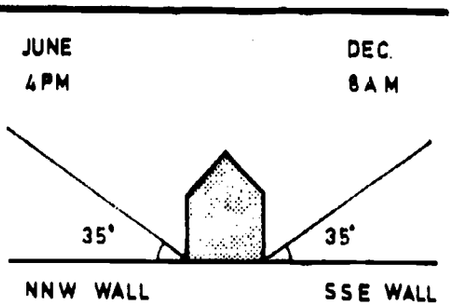
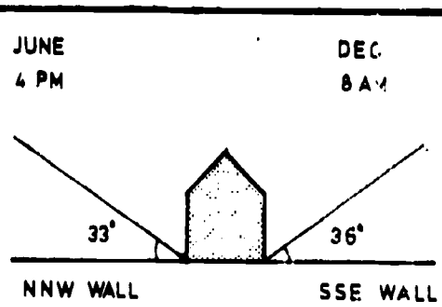
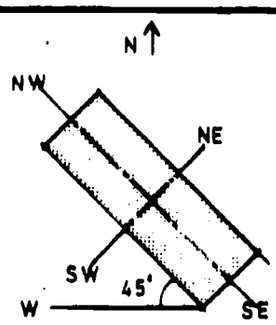
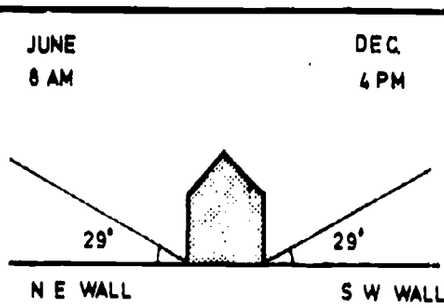
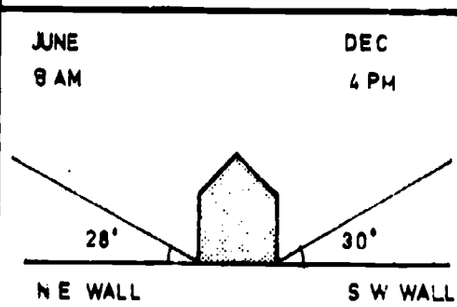
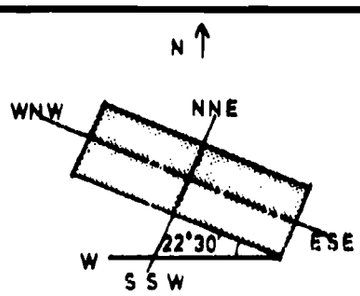
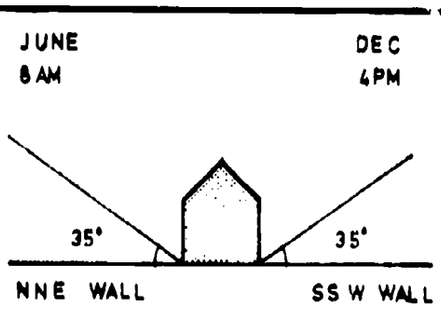
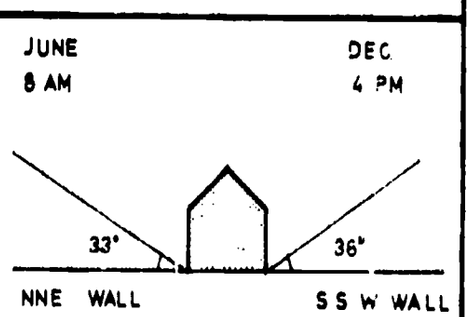
SUN SHADING DIAGRAM

CRITICAL VERTICAL SUN ANGLES
DURING THE SCHOOL DAY 8 AM - 4 PM
PROJECTED ON THE PLANE OF SECTION A - B

ORIENTATION	LATITUDE 4° N SECTION A - B	LATITUDE 2° N SECTION A - B
		
		
		
		
		

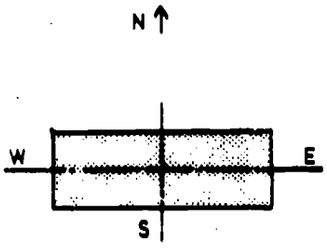
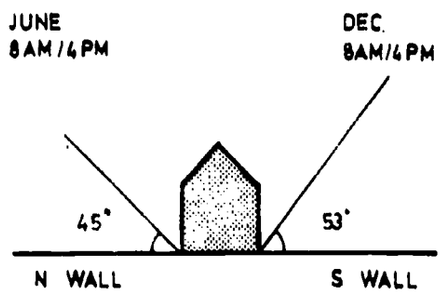
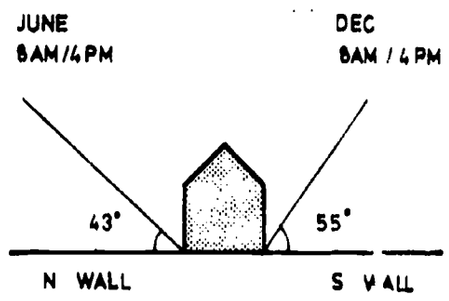
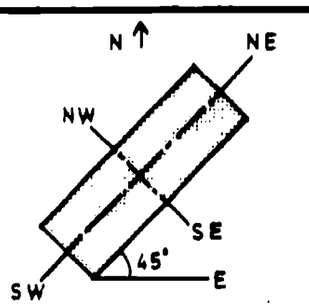
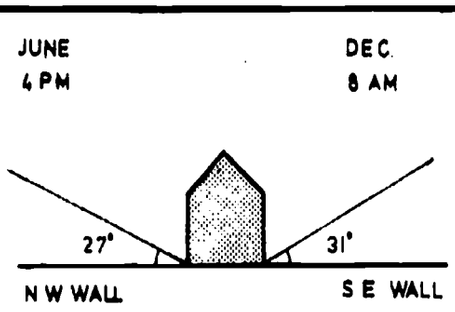
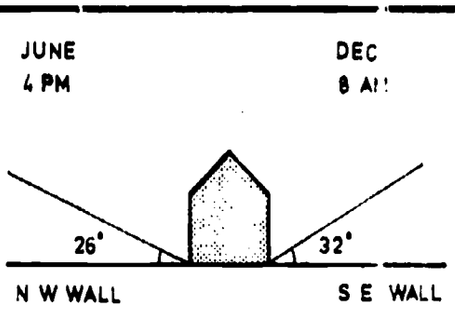
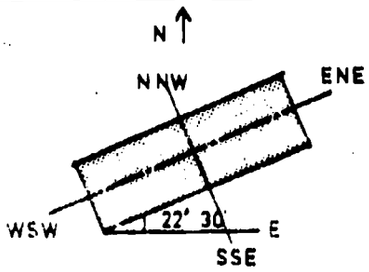
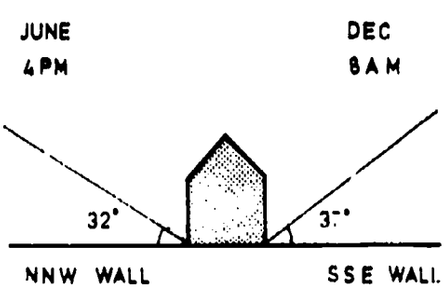
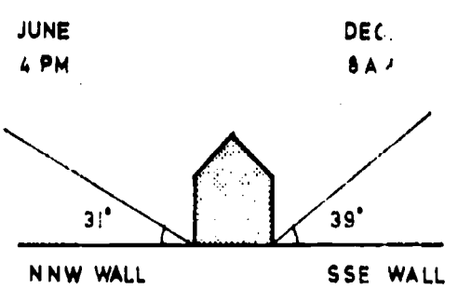
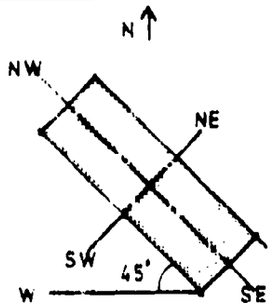
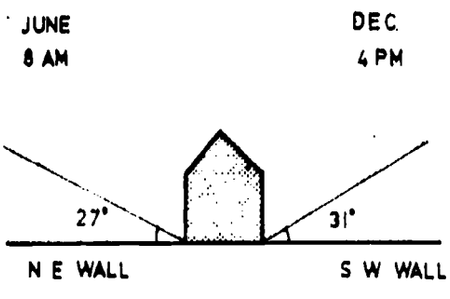
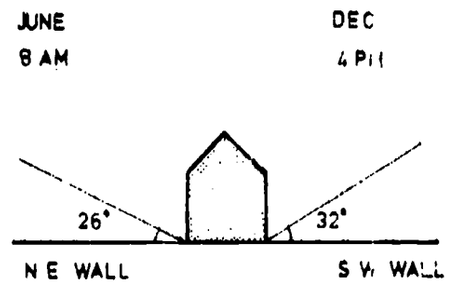
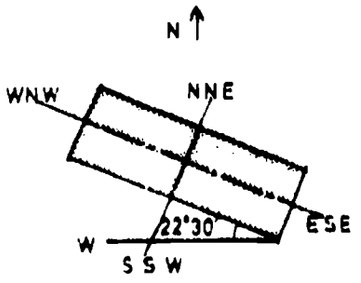
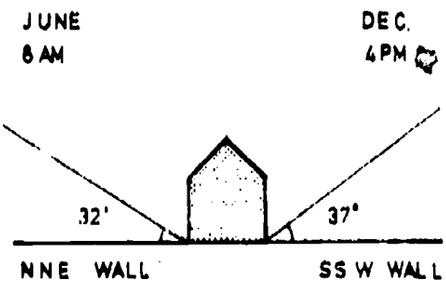
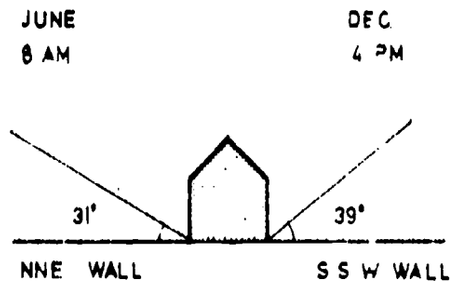
SUN SHADING DIAGRAM

CRITICAL VERTICAL SUN ANGLES
DURING THE SCHOOL DAY 8 AM - 4 PM
PROJECTED ON THE PLANE OF SECTION A - B

ORIENTATION	LATITUDE 0° SECTION A - B	LATITUDE 2°S SECTION A - B
		
		
		
		
		

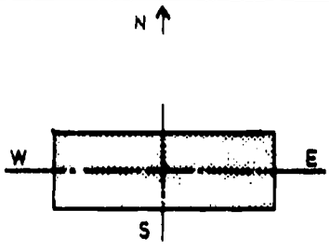
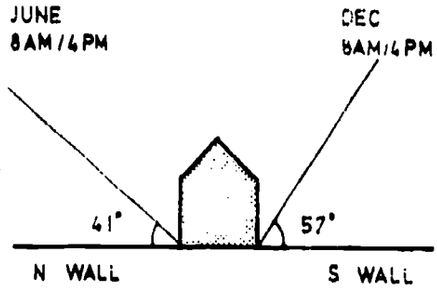
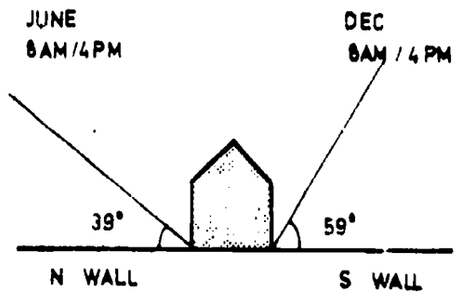
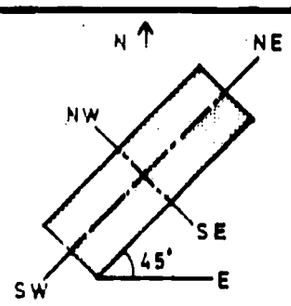
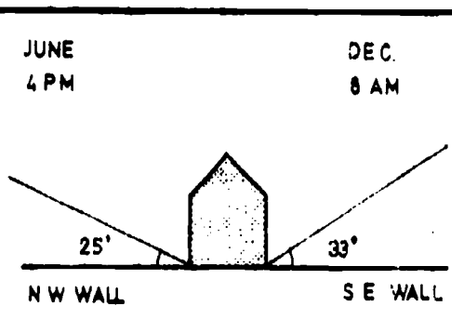
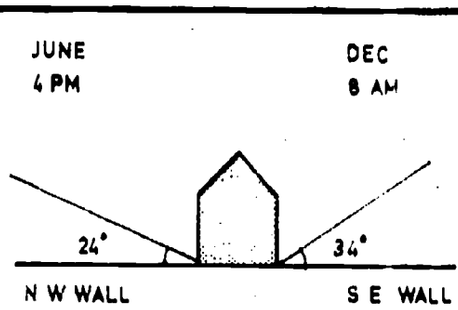
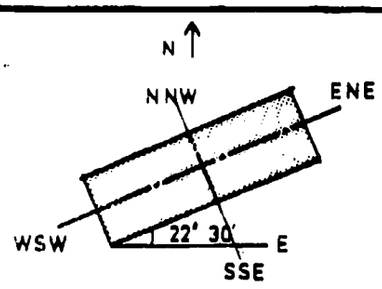
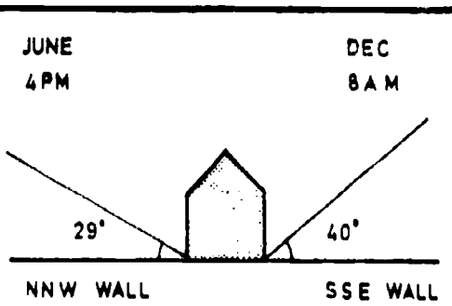
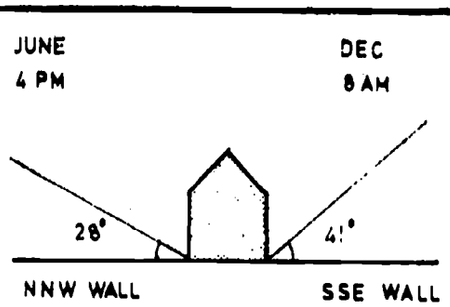
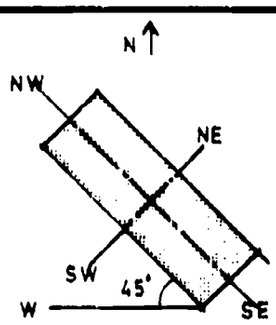
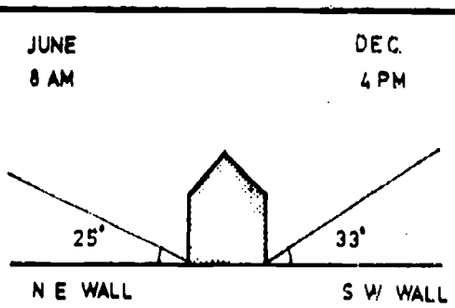
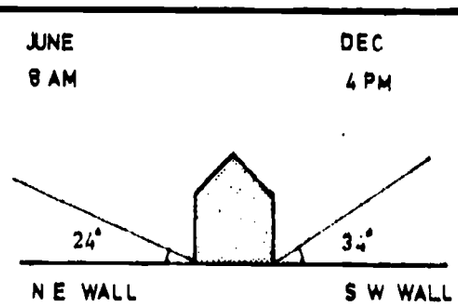
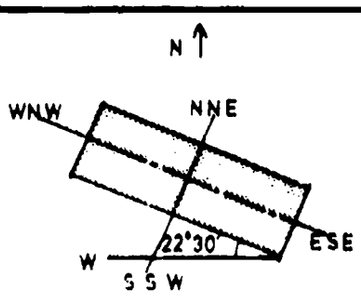
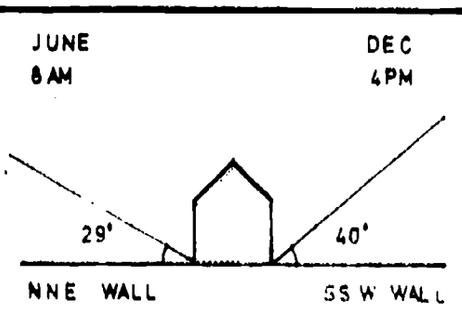
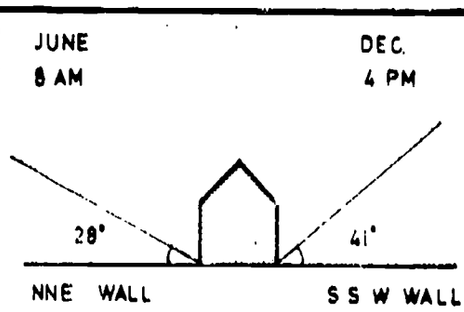
SUN SHADING DIAGRAM

CRITICAL VERTICAL SUN ANGLES
DURING THE SCHOOL DAY 8 AM - 4 PM
PROJECTED ON THE PLANE OF SECTION A - B

ORIENTATION	LATITUDE 4°S SECTION A - B	LATITUDE 6°S SECTION A - B
		
		
		
		
		

SUN SHADING DIAGRAM

CRITICAL VERTICAL SUN ANGLES DURING THE SCHOOL DAY 8 AM - 4 PM PROJECTED ON THE PLANE OF SECTION A - B

ORIENTATION	LATITUDE 8°S SECTION A - B	LATITUDE 10°S SECTION A - B
		
		
		
		
		

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   No. 16 " " " : China, Rep. of
   No. 17 " " " : Hong Kong
   No. 18 " " " : Indonesia
   No. 19 " " " : Philippines
   No. 20 " " " : Singapore